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Milan M5 Metro Extension: The “Strange Case” of Lotto Station

Giuseppe Lunardi, Luca Mancinelli and Massimiliano Tulipano Andreoli

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Abstract: This paper describes the construction of a deep station during the work on the extension of Metro Line 5 in Milan, Italy. Operating in an urban context that included the presence of an existing line (Milan Metro Line 1), the work had to grapple with some very particular problems so as not to interfere with the area's normal city life. Several construction choices and technical solutions were adopted to reduce impacts as much as possible and to suit local needs (hydromill diaphragm walls, top down and bottom up techniques, protected TBM (tunnel boring machine) break-in by false tunnels, precasted and casted solutions for internal structures and construction management, etc.). The contribution points out the attention to the issues that make this activity so particular for excavation, ground support and structural solutions, and also for the split between civil and tunnel works carried out simultaneously on the same site. Underground context, consisting mainly of sands and gravels with presence of water, is shortly presented also in terms of geotechnical parameters.

Key words: Construction management, underground, metro, top-down, precasting.

1. Introduction

In these pages, we present a contribution linked to the “strange case” of the Lotto M5 station, built in the framework of the extension of Metro Line 5 in Milan (Fig. 1). With respect to the other stations of this line, Lotto M5 presents some particularities that, because they were present along with others, required a delicate series of stratagems.

In general, the zone chosen for its construction is very urbanized, affected by the presence of buildings, palaces and heavily trafficked roads. The area is also located very close to Metropolitan Line 1 (M1) and the related Lotto M1 station with which there will be an interchange (Fig. 2).

These elements, together with the geotechnical context of the intervention, constituted of sands and gravels below the water table, caused the planning to be pointed in a specific direction by developing a particular construction system.

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In particular, downstream of the use of interpenetrating diaphragms can be realized with a hydromill, completed by a bottom buffer of cement injections, useful elements for creating an “impermeable box” which is indispensable for being able to proceed with the excavations. It is the support system that displays a particularity. It is in fact “hybrid”, constituted at the same time of active steel anchors, metal struts and entire decks realized with top-down technique. This apparently complex result represents the synthesis of a series of different necessities. In some areas of the station, due to the presence of the M1 galleries or of the Lotto M1 station, the anchors proved not to be feasible, requiring their replacement with a system of metal struts. Beneath the water table these elements were deemed incompatible with the construction on account of the time and technology needed to proceed in a suitable manner. In this case, they were replaced by top-down decks, realized during the descent phases and connected directly to the perimeter diaphragms.

Given the dimensions of the station, these decks could not be supported solely with the system of the

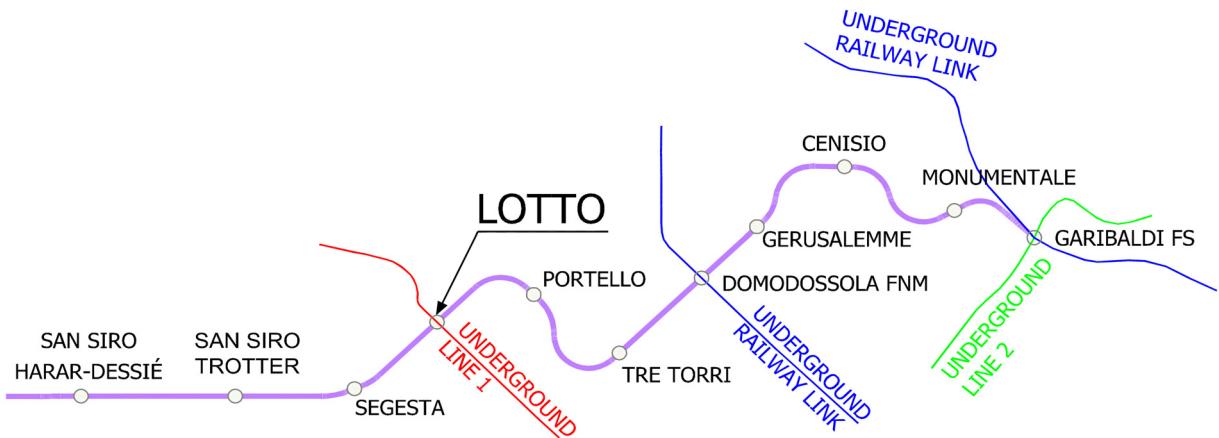


Fig. 1 Overview of Lotto station on Line 5 extension.

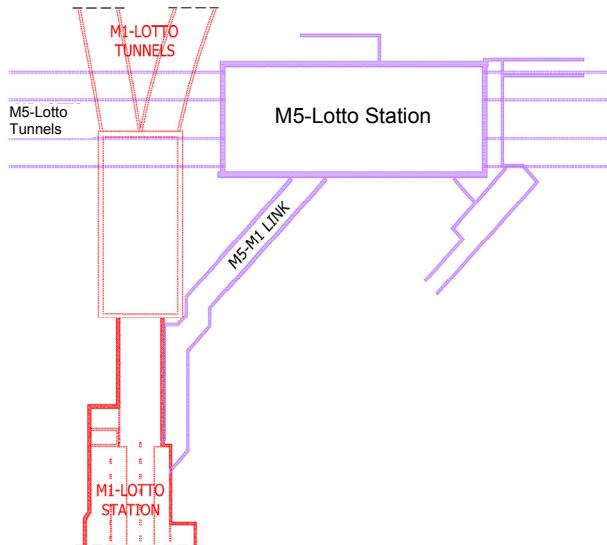


Fig. 2 Schematic layout of Lotto stations and tunnels (plan view).

perimeter compartments, however, by exploiting diaphragm technology, the work therefore proceeded with the installation of suitably positioned and founded metal pilasters.

Lotto M5 station has a particularity also for what regards the entry of the two TBMs (tunnel boring machines). Corresponding to the side foreseen for this break-in, there was no possibility of carrying out, unless partially, an adequate soil consolidation and waterproofing treatment. This buffer, necessary to keep the groundwater from entering the body of the station, in fact constitutes a zone in which the machine is protected, avoiding that break-in puts the interior and exterior of the station into hydraulic

communication.

Given the situation, two false tunnels were excavated, temporary structures useful in the same way for protection of the machine in the entry phase but built inside the body of the station. The false tunnels are watertight reinforced concrete sheaths able to accept the advance of the machine while resisting the working and hydraulic pressures linked to the presence of the groundwater. Their length is such as to allow the rings mounted by the TBM behind its body to be adequately seated in the perimeter diaphragms of the station, thus preventing any hydraulic communication between the interior and exterior of the station and achieving the same result as the buffer system described earlier.

For the machines' break-outs, the chosen system was instead that of external buffers, given the absence of particular interferences and the big advantage, in this case, of being able to proceed with their realization independently of the works in the station. Indeed, it is evident that construction of the false tunnel is possible only with the station completely excavated and partially realized.

Below, the themes proposed here are illustrated and discussed case by case.

2. Method

Lotto M5 station is the deepest on the entire Metro Line 5 (approximately 30 m from ground level to the

excavation bottom) and constitutes an interchange with Line 1 (Fig. 3).

From the realization standpoint, the excavations were supported by reinforced concrete diaphragms with both short and long term uses. The presence of an important hydraulic head (over 15 m) and the notable excavation depth required the use of a hydromill, a machine able to limit verticality errors and, thanks to interpenetration between primary and secondary diaphragms, ensure good water tightness. During the excavation phases, the diaphragms were supported by several rows of steel anchors and struts and by two decks realized with top-down technique. In the long term, the diaphragms are supported on the totality of the definitive decks.

Base waterproofing was ensured by means of a series of injections, while adding to the ground a mix of water, concrete, silicate and bentonite. The base slab of the station is connected by means of shear keys to the diaphragms, which, in addition to the weight of the station's internal structures, have a stabilizing function in relation to any long-term floating phenomena.

3. Geotechnical Conditions

The context in which the work took place, simply represented in Fig. 4, consists basically of sands and gravels (Levels 1 and 2) in the presence of the water table, even if also silty sands (Level 3) were found

during the survey phase. The characterization of the materials in the zone is fairly well known because the city of Milan already has three metropolitan railway lines, an urban link railway line and a large variety of underground structures for different uses. For design and calculation purposes, the underground context has been defined as described in Table 1 and 2.

The law that allows to deduce the value of Young's modulus for Levels 1 and 3 in MPa is, as an indirect function of the depth, defined as:

$$E = 1,000 P_a (\sigma_3/P_a)^{0.5}$$

where,

P_a : atmospheric pressure in MPa;

σ_3 : horizontal stress in MPa.

Table 1 Design parameters for cohesion, angle of friction and Young's modulus.

Level	c' (kPa)	ϕ' (°)	E (MPa)
1	0	35	see text
2	20	22	30
3	0	37	see text

c' : cohesion;

ϕ' : internal friction angle;

E : modulus of elasticity or Young modulus.

Table 2 Design parameters for natural weight and Poisson's ratio.

Level	γ (kN/m ³)	ν (-)
1	18	0.3
2	19	0.3
3	19	0.3

γ : natural soil weight;

ν : Poisson's ratio.

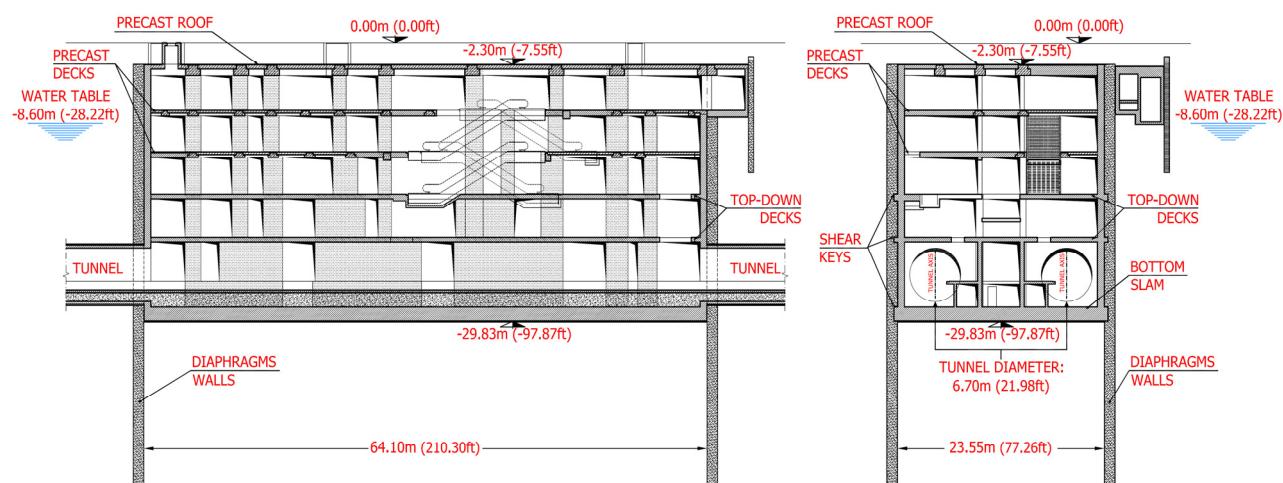


Fig. 3 Longitudinal section and transversal section.

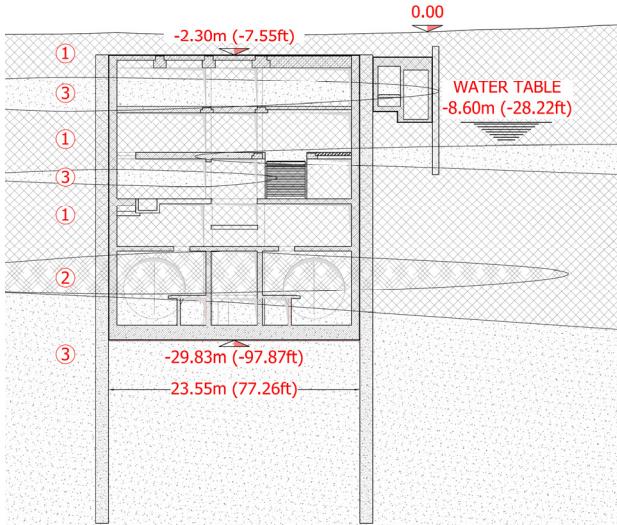


Fig. 4 Transversal section with geotechnical layout.

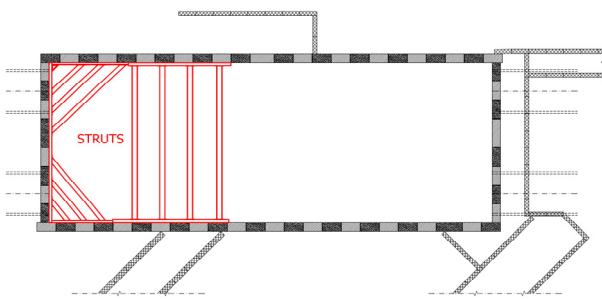


Fig. 5 Struts plan.

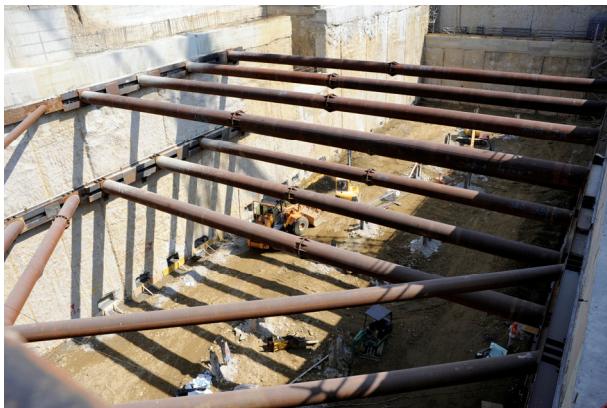


Fig. 6 Struts system.

4. Particular Design Aspects Linked to the Urban Context

As mentioned in the introductory section, some design choices resulted from the insertion of the work in a densely urbanized context characterized by important pre-existing underground structures,

constituted for example by the existing Lotto M1 station.

4.1 Two-Level Struts

The presence of the M1 section adjacent to the new station did not allow the realization of anchors for at least a third of the perimeter. As shown in Fig. 5 and 6, in this area, the anchors were replaced with metal struts. These struts have spans of up to 23 m and diameters of up to 90 cm (slenderness 70-110).

In addition to the usual operational difficulties connected with the realization of the bottom-up casting of the internal structures (e.g., interruption and resumption of reinforcement and pouring of the cavity walls beneath every row of struts), it was a contractual requirement to contain the realization times (Fig. 7).

This aspect led to the use of prefabrication technology for the three foreseen bottom-up decks.

4.2 False Tunnels inside the Station

At the entrances and break-outs below the water table of the TBMs from the stations (Fig. 8), soil treatments were carried out behind the pilings aimed at reducing the permeability. In order to avoid water inflows in the entrance/break-out phase, the plugs must be sufficiently broad, in the longitudinal sense of the station, to enable assembly of at least one segment ring before the cutter head goes beyond the grouted face. In many cases of excavation in urban environments, it is



Fig. 7 Excavation phase.



Fig. 8 TBM break-in from the Lotto station.

not possible to execute a complete treatment because of interferences with existing buildings or roads. To get around this problem, in the Lotto station worksite it was decided to make false tunnels, thus shifting the entry/exit phase of the cutters laterally within the station (Fig. 9).

The dimensions of the concrete blocks that constitute the false tunnels were derived as a function of those of the TBM, and the circumferential framing support for containing the radial pressures of the machine in the thrust phase is disposed externally with respect to the footprint of the shield. To avoid slippage and raising, the false tunnels are connected to the base slab by means of ribbed bars.

For waterproofing in the break-in and break-out phases of the cutters in the station, the advantage that the presence of the false tunnels offers inside the station is that of being usable in the presence of a partial treatment of the soil behind the pilings.

On the other hand, this temporary protection work presents the disadvantage of having to be demolished in any case since it interferes with the architectural layout of the station.

4.3 Separation Worksite Shaft/M1 Connection

A further aspect linked to the surface traffic regards the separation, also at the level of preparatory works, between the construction phases of the station shaft with respect to the exits and to the connection with the

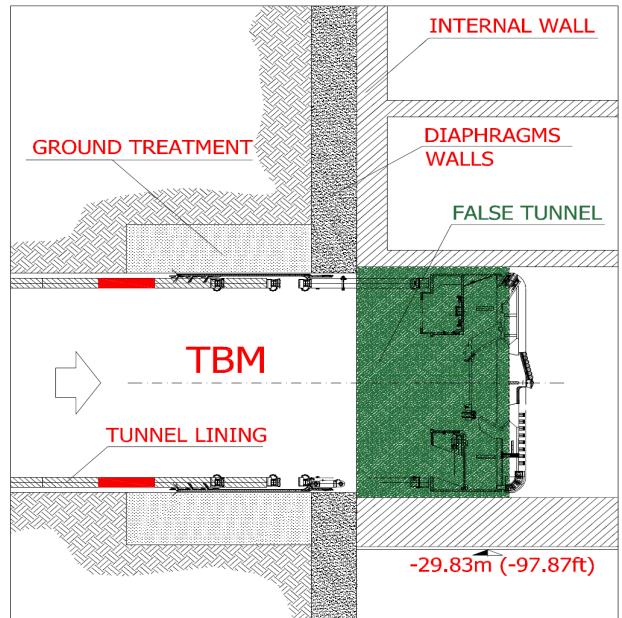


Fig. 9 TBM break-in.

M1, which in other situations presenting less interference has not been necessary.

In the case at hand, the internal structures of the station shaft, up to the pouring and the backfilling of the roof, were planned so as to divert the traffic on the station. This will make it possible to open the worksite in the adjacent area and to excavate the connecting corridor to Lotto M1 between pilings. Placed between the two structures, the station and the connecting corridor is a piling of reinforced concrete diaphragms that will have to be cut and demolished to open the connection. The choice of separating the work made it necessary to reinforce the piling, even if subject to future demolition.

5. Particular Design Aspects Linked to Worksite Requirements

The economic/organizational requirements of the worksite often affect the construction design of an infrastructure work. This section describes some design choices adopted as valid solutions to these problems.

5.1 Steel Anchors Head above the Water Table

The level of the water table in relation to the depth of the excavation often requires anchors with

submerged head. In these cases, it is necessary to use a more sophisticated drilling technology than that which makes it possible to realize anchors above the water table.

For this reason, the implementing enterprise requested that an alternative solution to the anchors be studied, which led to the use of a mixed top-down method (Fig. 10). By this, we mean that the decks realized in the first phase, together with anchors above the water table and struts, are part of the horizontal contrast system of the pilings. In addition, in this context, the top-down method was not used in the classic sense which calls for covered excavation. Indeed, intermediate floored retaining walls subject to an important state of membrane and bending stress are realized.

5.2 Top-Down Decks: Opening Sizes and Pouring Phases

The top-down decks of the Lotto M5 station have a short-term function as horizontal contrast for the pilings, and a long term one in which the slabs are subject to heavy gravitational and horizontal loads. This dual function determines a different load condition and a different geometry of the holes in the short and long term.

In this case, the enterprise requested larger opening sizes for lowering materials and machinery for service into the station worksite and the TMB worksite (Fig. 11). The construction system used gave the possibility of a separation of the TMB and station worksites. In this way, the activities were conducted simultaneously without interfering with each other.

To make the opening sizes conform to the architectural layout, pourings in the subsequent phase were necessary, connected to those of the first phase by means of mechanical joints (threaded/sleeved bars).

Temporary metal struts were placed in critical zones of the slab for more effective redistribution of the membrane stresses generated by the thrusts of the earth and water on the diaphragms.



Fig. 10 Top-down classic method vs. top-down Lotto M5 station.



Fig. 11 Top-down decks: opening sizes.

5.3 Precasted Decks

In order to speed up the delivery times of the work, the executing enterprise chose the prefabrication solution to realize three floors of the Lotto M5 station, including the roof (Fig. 12). The floors are constituted of prefabricated concrete beams reinforced with non-prestressed reinforcement and of slabs, lightened or solid according to the structural needs. The beams rest on the pilasters, dividing walls and supporting walls realized in the work. Structural requirements



Fig. 12 Assembly phases of beams and slabs.

linked to the geometric complexity of the floor in the area of the side escalators made it necessary to realize some portions of floor during the work.

5.4 Metal Columns Encased in Concrete Pilasters

The top-down decks were supported in the short term by metal struts founded on reinforced concrete diaphragms (Fig. 13) realized at the same time as the perimeter pilings. The beams are encased in lean concrete, removed in the excavation phase.

All the metal elements were calibrated so as to be kept inside the reinforced concrete pilasters definitively, although not being considered long term for resistance.

6. Conclusions

The “strange case” of the Lotto station required a particularly complex planning and decision-making process. Starting from the preliminary study, it was necessary to evaluate all the technological requirements, comparing them with the builder’s requests. A particularly important role was played in this by the general timing and especially the integration of the schedule of the work on the station with that of the tunnel system. This subject is a particularly delicate one, considering that the construction works inside the station were coordinated with the TBM break-ins and break-outs, with an extensive presence of plants and conveyors for mucking, and with particular attention to safety and control.

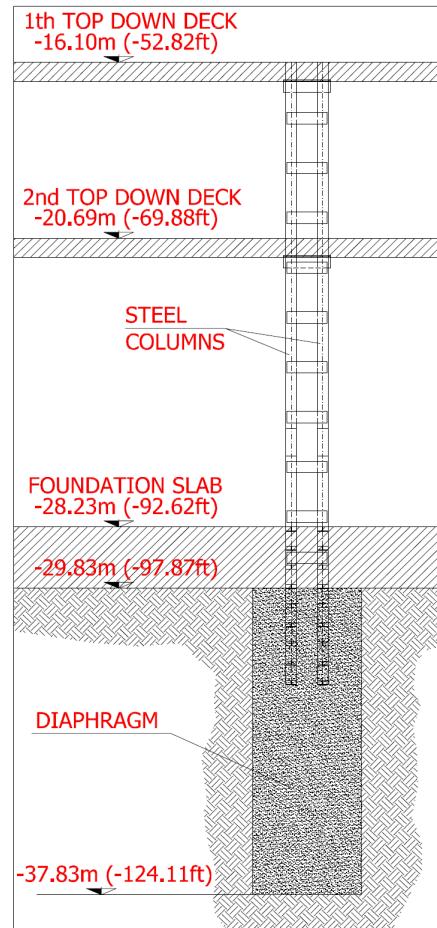


Fig. 13 Metal support columns-scheme.

Once all the main concerns were identified a synthesis was made, followed by a proposed solution which led to the construction of the work in a fast-paced process of discussion and eventual agreement on the choices.

In short, the Lotto M5 station represents a good example of a work in which the various passages that lead from the initial idea to construction were followed with success to overcome the many difficulties present. The structure, as described extensively in the foregoing pages, has a number of particularities linked to its inclusion in a dense urban fabric, the presence of a running metro line, the context of excavating in the presence of ground water, and work times which overlapped the tunnel digging activities with those of realizing the interior structures.

As known, building a metro station is one of the most complex and impactful activities in the area of

infrastructure. The difficulties of realization, as well as the inconveniences for the population during the construction phases, were “repaid” with a very important result for the entire collectivity, a result that enables an improvement in people’s lives through the mobility provided by public transport.

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Analysis of Vehicle Modification Practice in Bangladesh

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Abstract: With the shocking present vehicle growth over 10%, many vehicles are found to operate within urban areas and national highways of Bangladesh without having necessary registration and fitness papers. Uncontrolled vehicle modification practice has become a serious concern particularly for large vehicles, which leads the vehicle owners not to properly adhere to the vehicle fitness rules. The primary objective of this research is to reveal the extent of vehicle modification of different categories of vehicle. In this regard, field survey is conducted in major bus terminals and truck depots of Dhaka city to find out the issues related to rampant vehicle modification. Later statistical analysis is performed to obtain the most observed vehicle dimensions followed by local body workers. Finally, detailed questionnaire survey is performed on vehicle owners as well as the body makers as an attempt to reveal the poor quality of work performed by unskilled local workers. This paper would describe the findings of this research work along with appropriate remedial measures to control the unsafe modification of vehicles.

Key words: Vehicle modification, vehicle fitness, in-vehicle unsafe material, body maker of Bangladesh.

1. Introduction

Presence of defective and road unworthy vehicles plying on road poses serious threat to the safety issue of road system in Bangladesh. According to the statistics of BRTA (Bangladesh Road Transport Authority), total number of registered vehicles in Bangladesh up to 2013 is more than 2.1 million, among which 1.6% is bus and almost 5% is truck. With the present growth rate of vehicle over 10%, number of faulty vehicles is ever increasing and as a result road safety is compromised. Both physical and mechanical defects in vehicle, which no longer meet or conform to the rules and regulations of road traffic system can contribute to a crash or increase the likelihood of injuries to road users and depreciation of vehicle. According to the data collected from ARI (Accident Research Institute), from the year 1998 to 2010, among all fatal accidents 25% occurred due to bus and 3% due to truck traffic [1]. Also in absence of periodic replacement practice of defective parts,

number of aged vehicles is rising in road. Research conducted in Canada shows that the proportion of fatalities, serious injuries and collisions for the occupants of aged defective vehicles (15 years and older) increases and is approximately two and a half times higher than the average for occupants of all vehicles [2].

However, if vehicle physical condition is highlighted, it is critically observed from pedestrian safety analysis in Al-Ain city of the UAE (United Arab Emirates) that vehicle size and design do not affect the anatomical injury distribution and severity. In UAE, high-impact speed is dominant over vehicle type when it comes to severity and pattern of injury distribution [3]. Thus, transport systems in developed areas like UAE, London and elsewhere are actually aiming to reduce traffic speeds in order to decrease traffic mortality. Similarly, according to another research conducted in USA (United States of America), it is derived that there exist little relationship between vehicle wheelbase and casualty risk in frontal crashes [4]. However, in developing countries like Bangladesh, it is likely that vehicle

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physical defects are more often a factor in accidents as vehicle condition is generally much worse. The vehicle fleet is usually older with many vehicles imported as second-hand from other countries. And there may be difficulty in obtaining suitable spare parts. Though adequate legal provisions have been made in the "Motor Vehicle Ordinance" of Bangladesh to conform standard vehicle condition and allowable physical dimensions, unfortunately these legal provisions are neither observed properly nor enforced strictly in Bangladesh. Taking advantage of weak legal enforcement, uncontrolled vehicle modification is spreading as a contagious social disease. The unauthorized change of physical condition of the vehicle is done after buying vehicle, whether it is a fresh stock or a secondary purchased vehicle. Also, the extent of multiple periodic modification of vehicles is seriously noticeable while maintaining the vehicle or recovering it after any serious crash. This uncontrolled vehicle modification of heavy vehicles often prevents the owner from renewing fitness certificate which is considered as mandatory every year as per local constitution. Such alarming situation prevails in Bangladesh as local body makers, without any academic or institutional training, perform modification where owners mainly take the role of engineers. The scope of this paper includes the comprehensive examination of the extent of local illegal modification practice. It is important to comprehend the impact of unskilled local body workers on improper modification work. To do that appropriate share of resources is given to find out the quality of vehicle body works performed in auto workshop with a view to improve local vehicle life expectancy and performance.

2. Why Is Vehicle Modification an Issue?

In Europe, prevailing "Safe System Approach" acknowledges that the design of vehicles must be based on human limitations including tolerances to physical force. This is implemented through national

strategic plans such as "Vision Zero" in Sweden or "Sustainable Safety" in the Netherlands. Unlike those countries, roadway safety is often compromised in Bangladesh because of excess presence of road unworthy modified vehicles. Nevertheless, "Motor Vehicles Act, 1984" presents a complete definition of vehicle modification:

"Modification in a relation to a motor vehicle means that it is no longer in conformity with the regulations when any of the items has been modified contrary to the regulations or replaced or equipped by an item which is not the prototype or not Homo-logical or when using them is considered prejudicial to safety or to the environment but shall not include wear of an item and the resulting condition" [5].

However, according to field survey unsafe modification practice of public vehicles (large buses, mini buses and human haulers) and goods vehicles (large trucks, covered trucks and medium trucks) prevails here for more than three decades. Modification practice significantly varies with vehicle types. Besides owners' profit earning motive, the situation has also worsened by the inexperienced local body makers, who do not possess any formal training or institutional skill. More importantly, as stated by the section 47 of "Motor Vehicle Ordinance 1983", every vehicle needs to renew fitness certificate every year under proper inspection of BRTA (Bangladesh Road Transport Authority). Nevertheless from survey conducted by BRTA, it was found that about 20% of the buses do not have fitness for operation [6]. Additionally, these unauthorized modified vehicles often induce roadway collision with additional body features (like sharp-edged bumpers, horizontal angles etc.). According to the collected data of ARI, among the total recorded number of vehicles causing accidents in 10 years (2000-2010) in the area under the jurisdiction of DMP (Dhaka Metropolitan Police), 17.9% vehicles were reported to have no valid fitness certificate [1]. Among the heavy vehicles, fitness

certificate was not found for 9.8% buses, 10.7% minibuses, 13% trucks and 11.9% heavy trucks. Such gloomy findings lead to strong belief that local vehicle modification is one serious issue to investigate considering high collision rate of such vehicles.

3. Trends and Impacts of Vehicle Modification

Local vehicle modification is done mainly on commercial vehicles, i.e., buses or trucks to give them

a distinctive appearance or to improve vehicle performance. Owners intentionally do that to add desired features in order to modify the carriage capacity without following manufacturers' instruction or any distinctive scientific approach. This incident particularly alters the vehicle center of gravity, makes them unstable and increases tyre burst accidents on road. However, Table 1 is furnished with the performed modification dimension of heavy vehicles as has been collected by field interview of body making

Table 1 Summary of field survey result of modified vehicle body configuration performed by local body-makers (for the year 2011 and 2012).

Vehicle type	Vehicle classification	Model/parts	Model name/dimension
Bus	Large bus (more than 40 seats)	Engine	Modified
		False chassis	Offset from chassis: 0.61 m (Hino), 0.91 m (Tata)
			Increases up to 52, 57, 62 number of seats
		Seat number	Seat area cross section: 0.46 m × 0.46 m
	Mini bus (between 16 to 39 seats)		Seat to seat distance: 0.71 m
		Engine	Modified
		False chassis	Offset from chassis: 0.76-1.07 m
		Body	Inner clear height: 1.91 m (if roof-top fan is not attached); 1.83 m (if roof-top fan is attached)
			Length 7.62 m (authorized length: 6.4 m)
		Seat number	Width 2.19 m
Truck	Heavy truck (three or more axles)	Seat dimension	42 seat (authorized: 31 seat), 21 seat (authorized: 30 seat)
			Width of three seats cover area: 1.14-1.22 m (authorized width: 1.37 m)
		False chassis	Width of three seats cover area: 0.71-0.76 m (authorized width 0.91 m)
			Seat center to center distance: 0.51 m (authorized distance: 0.66 m)
		Carrier body	Offset from chassis: 0.76-1.22 m
	Medium truck (two axles rigid trucks)		Cross section of carrier: 2.44 m × 2.44 m (covered truck)
			Length: 5.49-6.1 m (authorized length: 5.49 m)
		External bumper	Width: 2.44 m
			Width extension: 0.11 m on both side of headroom (covered truck)
			Offset from front of headroom: 0.05 m
Light truck (small trucks up to 3 t payload)	Carrier body		Offset from back of the carrier: 0.1 m
			Bumper thickness: 0.005 m
		External bumper	Bumper height: 0.51-0.76 m
	False chassis		Offset from chassis: 0.3-0.91 m
			Cross section of carrier: 2.13 m × 2.13 m (covered truck)

workers who are engaged in this work for more than 10 years.

From the enlisted modified dimensions of Table 1, it is clearly perceived that owners, compromising service quality, are stretching the performance of vehicle parts beyond their average life expectancies. Lack of attention towards frequent maintenance practice is one of the primary causes of modification. Moreover, more complex modification trends than past are found after the field survey of this research work. In previous research, some known practiced modifications were mentioned, like making of one type of vehicle on another type of vehicle chassis, projecting vehicle bodies beyond maximum dimension specified by the manufacturer, altering seating arrangement of bus, fixing additional features like bumpers, rooftop railing, ladder, etc. [7]. But recent research has found that many new trends of modification are invented, for example adding external metal plates in exterior and interior side of chassis of trucks, fixing additional angle on urban vehicle (specially urban buses), relocating external rear view mirrors inside of the urban vehicles, etc. [8]. Some of the observed dreadful scenarios of vehicle modification from field survey in the year 2012 are shown in Fig. 1. These risky alterations of vehicles increase extra material cost for owner, threat the vehicle's reliability, raise questions about the vehicle's legal compliance, compromise public perceptions to the service quality of the public vehicle

and above all reduce the expected service life of a vehicle. All these findings of the latest survey do not come as a surprise, rather it confirms the continuity and serious deterioration in the condition of the modification practice. Considering the impacts, a grievous conclusion can be drawn without hesitation that neither modification practice has any positive effect on vehicle nor the modified vehicles can ensure traffic safety. Poor authoritative performance by BRTA can be solely considered as the responsible factor of such widespread unregulated practice. It is observed from a comprehensive research conducted on vehicle inspectors in UAE that 17% of them think private companies can help in the inspection process as the inspection center increases, which will ease on people, prevent over crowd, and offers a better service [9]. Considering this outcome, it is high time to think about participation of private companies in heavy vehicle fitness checking procedure.

4. Research Methodology

Detailed field survey is conducted for one year (started from December 2011 and concluded at December 2012) in major three bus terminals in Dhaka (Gabtoli, Sayedabad and Mohakhali bus terminals) and three truck depots (Gabtoli, Tejgaon and Kamalapur truck depot) in order to reveal the degree of rampant vehicle modification. The vehicle body measurement survey is performed with measuring tape of millimeter accuracy on randomly

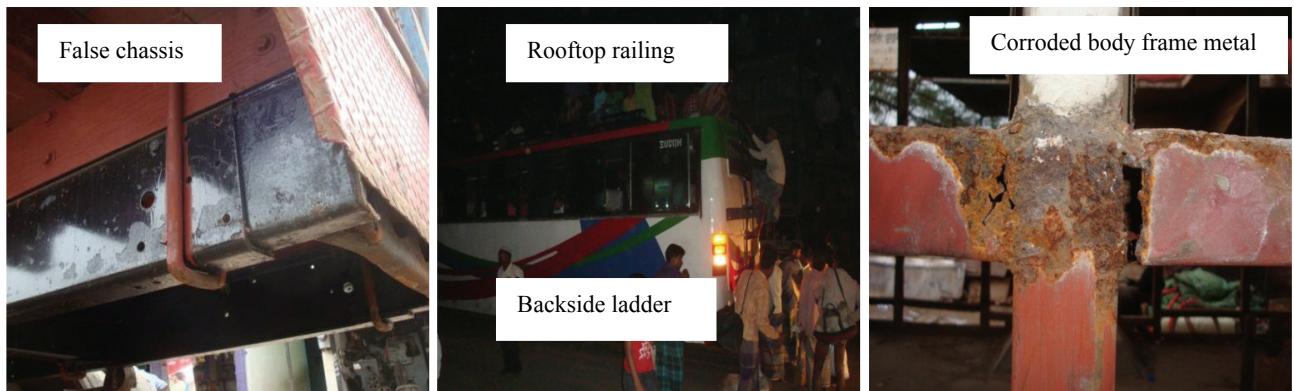


Fig. 1 Observed poor vehicle modification and maintenance practices during field survey.

taken 30 large buses, 20 mini buses and 20 trucks (uncovered and covered trucks each). Moreover, detailed vehicle condition survey is undertaken simultaneously on same vehicle samples. Finally, 35 local body workers are interviewed based on the prepared questionnaire survey to investigate nature of the modification work.

5. Analysis and Discussion

5.1 Analysis of Measured Vehicle Dimension

Field measurement is documented keeping the allowable parameters from Motor Vehicle Rules, 1997 and Motor Vehicle Rules, 1940 in mind [10, 11]. Some statistical analysis is performed on the available vehicle dimensions from field in order to reveal most performed vehicle body configuration. Table 2 is presented here with the summary analysis of collected

field data to find out the deviation of individual vehicle feature from the permitted limit. It is distinctly evident from Table 2 that as far as local vehicles are involved, violation of permitted dimension is a common practice in Bangladesh.

It is clear from Table 2 that weighted average value (7.73 ft.) of front overhang of large buses exceeds the allowable limit (6.9 ft.) by a distinct deviation of 12%. Also, this table verifies the tendency of majority of vehicle owners to stretch the rear overhang by attaching false chassis on the rear side of vehicle. It is derived that the weighted average value (8.83 ft.) of rear overhangs for mini buses exceeds the allowable limit (5.92 ft.) with a maximum deviation of 49.7%. Thus, almost half of the mini buses are arranged with extra space surpassing original passenger carrying capacity. Moreover, with reduced seat area (5.8% less

Table 2 Summary of statistical analysis of local vehicle dimension (for the year 2011 and 2012).

Vehicle type	Observed vehicle feature	Statistical characteristic	Vehicle measurement
Large bus (wheel base varies in 4.72-5 m range)	Front overhang (m)	Frequency analysis range of maximum percentage (69%)	2.34-2.44
		Weighted average	2.36
		Allowable length	2.1
	Rear overhang (m)	Frequency analysis range of maximum percentage (50%)	3.34-3.64
		Weighted average	3.79
		Allowable length	3.2
Mini bus (wheel base varies in 3.61-4.2 m range)	Seat dimension (m^2)	Frequency analysis range of maximum percentage (55%)	0.41-0.44
		Weighted average	0.45
		Minimum seat area	0.48
	Rear overhang (m)	Frequency analysis range of maximum percentage (60%)	2.54-3.01
		Weighted average	2.69
		Allowable length	1.8
Covered medium truck (wheel base varies in 4.93-5.41 m range)	Rear overhang (m)	Frequency analysis range of maximum percentage (30%)	2.95-3.05
		Weighted average	2.78
		Allowable length	2.47
	Bumper front projection (m)	Frequency analysis range of maximum percentage (60%)	0.61-0.71
		Weighted average	0.61
	Bumper height (m)	Frequency analysis range of maximum percentage (50%)	0.51-0.61
		Weighted average	0.51
Uncovered medium truck (wheel base varies in 4.19-4.8 m range)	Projection of front carrier beyond headroom (m)	Frequency analysis range of maximum percentage (45%)	0.2-0.305
		Weighted average	0.22
	Bumper front projection (m)	Frequency analysis range of maximum percentage (65%)	0.41-0.51
		Weighted average	0.35
	Bumper height (m)	Frequency analysis range of maximum percentage (50%)	0.61-0.71
		Weighted average	0.61

than minimum seat space), these mini buses pose an open physical threat for long route travellers, who are compelled to sit in this modified seats with limited movement for a long time interval. Another dreadful aspect of reckless modification is the external steel bumper of medium trucks. With sharp edges, these bumpers allow trucks to move on national highway as “The Killer Giant on Road”.

Furthermore, Fig. 2 shows the summary of collected field data from the year 2011 to 2012. Close observation of Fig. 2 reveals the unexpected degree of poor local vehicle modification. It shows that 86.7% of the 30 large buses exceed length of front overhang while all large buses surpass the limit of rear overhang. Also, for more than three-fourth of overall sample of large buses (76.7%) the overall width of large vehicle is found to exceed permitted dimension. However, intension of squeezing maximum number of seats is clearly perceived with limited space for legroom between seats in 60% of the 20 minibuses. For goods vehicle, 85% of the 20 covered trucks are reported to exceed allowable length of rear overhang. On the other hand, the back carrier of uncovered trucks has offset on both sides beyond truck cabin. For this research, this offset for carrier side is found to exceed limit of side overhang for 25% of the 20 uncovered trucks. All these are nothing but inevitable indicator

of increasing grievous practice uncontrolled vehicle local modification practice.

5.2 Analysis of Vehicle Condition Survey

It is mentioned earlier that local road safety is primarily threatened by risky modification feature, like side projection of truck carrier beyond head-room and lateral angles fixed externally with truck carrier or bus. Large vehicle condition survey from local field investigation is accomplished with a view to find the extent of modification practices which rise questions regarding this safety issues and the detailed analysis is presented in Fig. 3. It is found from Fig. 3 that 20% of total surveyed 20 covered trucks and 80% of total 20 uncovered trucks are dangerously projected beyond front headroom, although any unsafe alteration of vehicle is restricted by local constitution [5]. Such projection has a direct effect on safety issue by inducing side blind spots of local trucks. According to a research conducted in United States for the period of 2003-2007, although highest number of impact for trucks occur in front side (62.5%), side collision rate is also significant. Almost 15.5% of the total impact occurs in left hand side of the driver and 6.5% of them occur in right hand side of the driver [12]. Such impacts are more serious in developing countries like Bangladesh, as locally modified truck drivers cannot

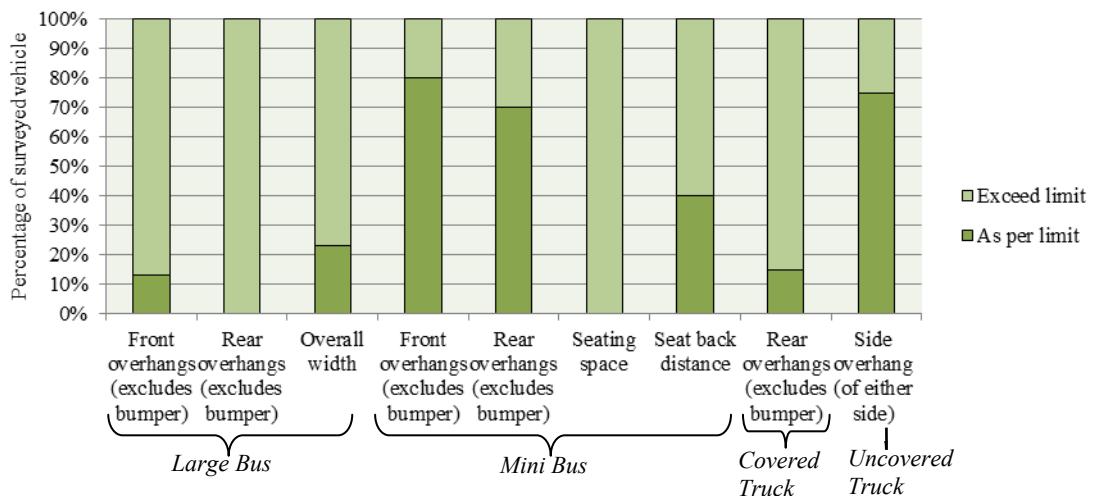


Fig. 2 Summary of measured vehicle data analysis (for the year 2011 and 2012).

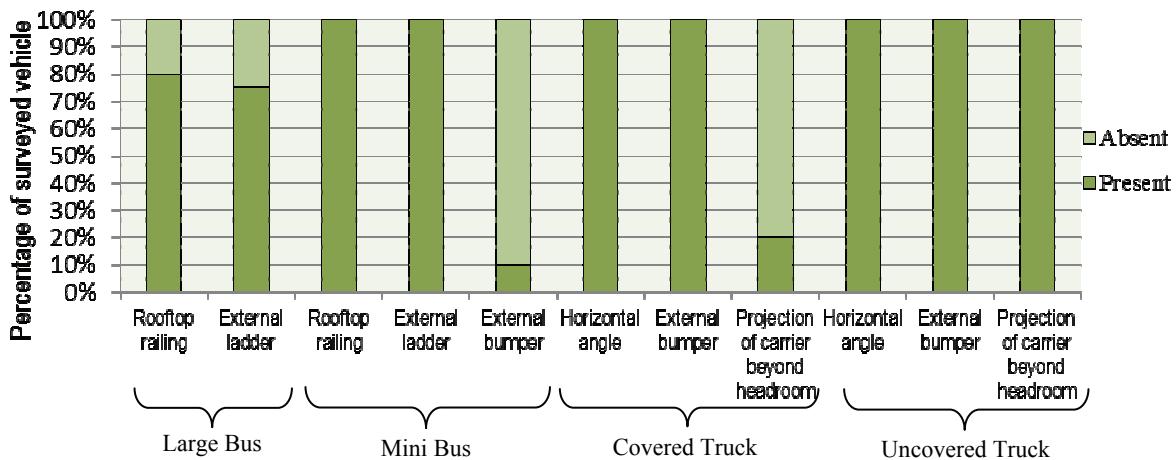


Fig. 3 Summary of vehicle condition survey result (for the year 2011 and 2012).

identify objects at an angle of 15° made with the side of truck headroom or cabinet. Here Fig. 4 shows this situation for a locally operational uncovered truck which was taken during the field investigation from Gabtoli area. Besides presence of sharp edged bumper and risky steel angles in all uncovered trucks reflect the shocking extent of illegal modification. For buses, it is believed that extra features like rooftop railing encourage overloading of goods or passenger and increase potential risk of passenger falling from roof at critical locations like sharp turn or frequent undulation. According to a research on accident analysis, out of total 1,011 accidents occurred near Jamuna Multipurpose Bridge, 50 passengers' fall-down incidents happened from rooftop and most are recorded as fatal or severely injured [13]. Majority

of large buses (80%) along with all minibuses with rooftop railing in recent study disclose that, this unwanted situation of fall-down incident will continue in near future unless earnest preventive measures against illegal modification are implemented.

5.3 Analysis of Local Vehicle Owners and Body Workers Characteristics

Alteration of vehicle physical condition widens the scope of deviation of performance from standard vehicle. Inconsistent complex modification is the consequence of fragmented ownership of heavy vehicle fleets. Commercial vehicle owners deliberately take the risk of random alteration of vehicle parts. Field investigation exposes that scrap steel is used for altering chassis and vehicle body while



Fig. 4 Side black spot induced by projected local truck carriers.

angular bars are mainly used for rooftop railing and in-vehicle structures like seats. Use of locally made glass instead of toughened or tempered glass has become widespread especially in window glasses of urban vehicles. As urban vehicle drivers always show aggressive attitude while moving on road, these low quality glasses pose serious threat in case of side collision. By tradition, local modification is performed by a group of naive body workers, who perform mainly under the supervision of an experienced senior. With the growing number of local workshop, number of amateur workers is increasing. During field survey, some of them are observed to perform vehicle body work alone without any guidance. Simultaneously risk is also increasing as no investigation is performed on the accomplished task, neither material checking nor inspection of welding. Hence quality of work solely depends on performance of body makers. Findings of the investigation on detailed characteristics of 35 local body workers from Dhaka are enlisted in Fig. 5 for the time range 2011 to 2012. It is distinctly visible from this figure that major portion of body workers (80%) has no institutional skill; rather they follow the instructions from senior workers. While servicing, mainly they apply their own perception (74%). Specification is mainly followed in renowned

workshops, while in local workshop about 6% workers replicate from picture of popular models. Meanwhile being the only earning member in family, overtime working beside regular working hours (8 h) is preferred by all body workers. Rush of limited time (20%) and budget restraint (66%) accompanied by monotony of working overtime leave a wide scope of questioning the quality of works performed by body makers. Another crucial factor is the poor working environment dominating in local workshops, where workers perform in a hazardous condition without safety precautions as shown in Fig. 6 which was taken from bus workshops in Gabtoli area. No local workshops are found with adequate fast-aid kit, fire extinguishers or gas masks. Even some perform without helmet or gloves while welding work, thus serious injuries like vision problem, skin burn and noise disturbance are very common in local body workers. Another shocking aspect is the existing number of child labors performing in local vehicle body shops. It is derived from a report of UNICEF that, in the year 2002-2003 number of children (aged 5-17 years) engaged in hazardous labor (auto workshops, welding, etc.) is 1.3 million [14]. The prevailing unsafe working situation poses not only a serious threat to the normal physical growth of these

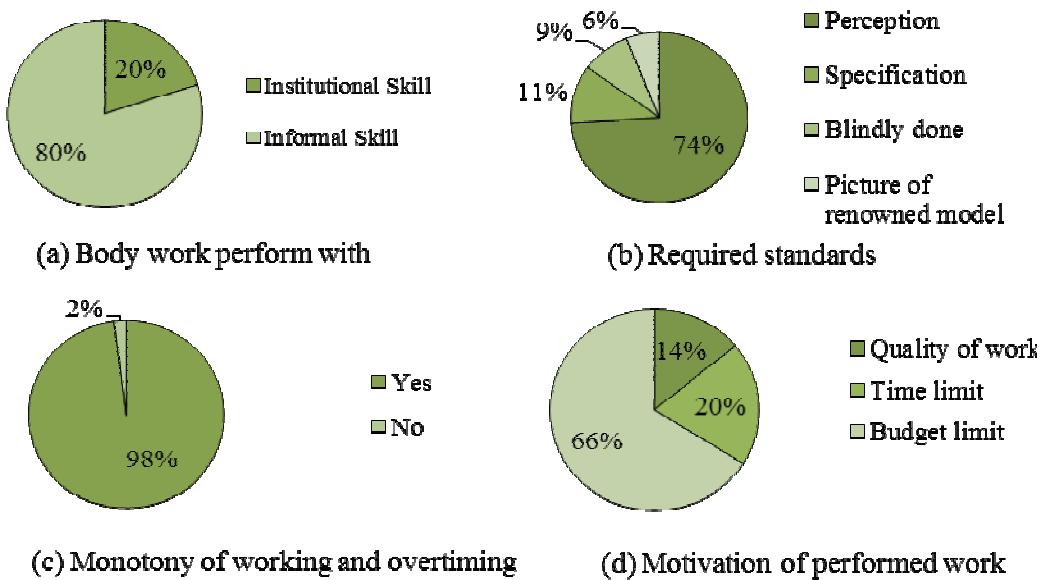


Fig. 5 Characteristics of local vehicle body workers (for the year 2011 and 2012).

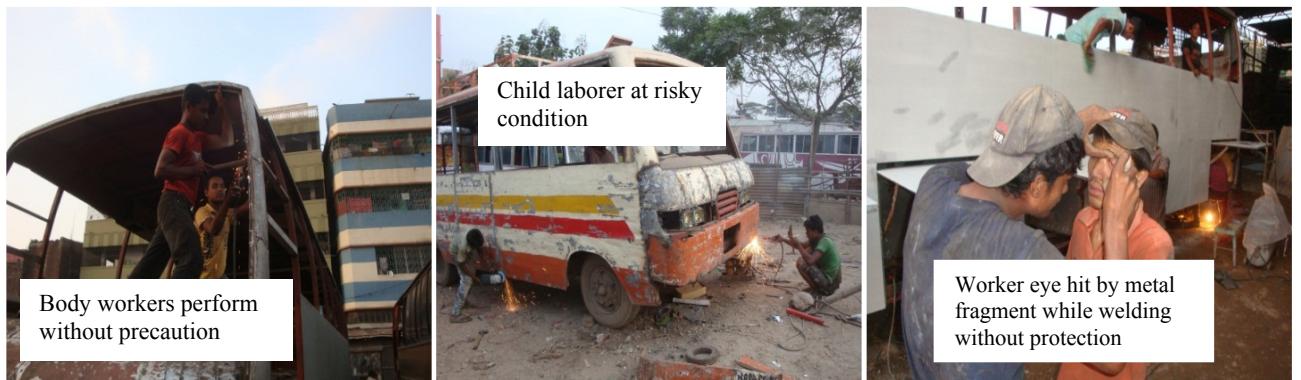


Fig. 6 Poor working environment dominating in local workshops.

children, but also many of them are found with disturbing mental disorder as an effect of working without necessary counter measures in such polluted surroundings. This in long term affects the quality of the modification work and also thus leaves a wide scope to question about the accomplished work.

6. Conclusions and Recommendations

As regular vehicle fitness checking is one of the main tools to control such uncontrolled vehicle modification practice, main responsibility lies with BRTA. Many of the modification features (like body angle, ladder, in-vehicle material, external bumpers etc.) are clearly identifiable. Strict vehicle fitness checking without any compromising can help to minimize the problem quickly. Recent emerging procedure of digital registration can be thought as a helping tool to regulate large vehicle fitness. Also, such grim findings from the study about degree of vehicle modification and body worker performance emphasize the need for taking instant initiatives like random roadside inspection of vehicles including the police and vehicle inspectors day and night to encourage compliance with road safety standards. Besides before further modification practices are introduced, rising safety awareness among owners and drivers about the adverse effects of reckless vehicle alteration can help for a long run. As in Bangladesh, the number of vehicle is on a rise with an alarming rate, it is becoming difficult day by day to conduct vehicle inspection with limited manpower, equipment

and infrastructural setup. Often the vehicle inspection centers in Dhaka city are found under pressure of excessive presence of vehicle. Crowded centers prevent inspectors from conducting a comprehensive and effective inspection, thus many vehicle features are overlooked or ignored during local vehicle inspection. This should be avoided to assure quality control. Moreover, immediate needs of privatization and short time based fitness renewal system (like Singapore and UK) are suggested by local law enforcing authority for a better service quality. Uniformity of testing equipment like exhaust gas analyzers, measurement of headlights focus, side slip testers, brake testers, and tire quality device is needed to be prioritized to have arrest the rising number of aged road-unworthy vehicles. To do that, law for breaking down the tradition of fragmented ownership of vehicle fleet is to be established. Similarly, strict law enforcement is to be confirmed to encourage the owners to consolidate the vehicle fleet. Most importantly adequate academic knowledge and institutional training should be made obligatory for local body makers. Age verification of workers by government and workshop owners is needed to be prioritized to stop the rising number of child laborers. As the extent of modification is continuing for a good time span, the regulatory body and law enforcing authorities are to be blamed equally. Legal provisions for standard vehicle feature and vehicle maintenance practice have been made in the Motor Vehicle Ordinance, but unfortunately they are not enforced

strictly in Bangladesh. No doubt exists about the upcoming challenges in near future for concerned authorities; however strong determination and co-operation of both government authority and vehicle owners will help to overcome the current situation in near future.

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Investigation of the Skid Resistance at Accident Occurred at Urban Intersections

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Abstract: Skid resistance of road surface plays an important role on urban traffic accidents. It is thought that reduction of surface microtexture leads to reduced skid resistance. Hence, it affects driving safety negatively and may cause traffic accidents. This paper is about the effect of skid resistance and intersection safety. Urban four leg signalized intersections were selected from Isparta city. The surface frictional properties were measured and it was tried to find critical skid resistance value with the help of British Pendulum Tester. Macro texture values of the intersections were determined with Sand Patch test and concluded that surface macro texture contributes to skid resistance. An analysis technique based on probability theory has been used. This method is used for expounding the interaction between skid resistance-intersection and accident rates. After the study results are evaluated, it is understood that pavement roughness is very important for urban intersection safety measures.

Key words: Microtexture skid resistance, macrotexture, intersection safety, traffic accidents.

1. Introduction

Traffic accidents are of great concern for road and transport departments around word, because they cause vital loss and dangers for the public. Also, traffic safety is the most important responsibility of anyone involved in urban road transportation. This applies at all stages from initial design, selection of materials, road geometric design to use of the road by the user.

Most of studies proved that extremely many accidents occurred at-grade intersections although intersections cover only a small part of the highway system. From many research studies in the United States, it has been identified that 50% of the total accidents happened at intersections [1]. Also, statistics prepared by the Ministry of Transport in New Zealand show that rural crashes are dominated by loss of

control incidents whereas urban crashes are dominated by incidents at intersections [2]. However, according to statistics in Turkey, 40%-60% of traffic accidents are in urban and rural road junctions [3]. So, urban intersection safety research studies are necessary studies for urban transportation systems.

Road engineers and users are also particularly concerned with the safe passage of vehicles that operate over them. One aspect of this safety is that there be adequate traction or friction between tyre and road surface to sustain driving forces and to allow stopping within safe limits [4]. This aspect of safety is tackled under the general designation of skid resistance. The skid resistance of the surface of a pavement is one of the important factors in determining the overall safety of an intersection.

The phenomenon of pavement surface skid resistance involves the complex interaction of pavement, vehicle and environmental factors [4]. In addition to this, intersection accidents are generally uncontrolled events and are dependent on a number of

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inter-related factors such as driver behavior, traffic conditions, travel speed, intersection geometry and environmental condition, and vehicle characteristics. So there are many parameters that affect the safety of an intersection.

To investigate the interaction of pavement roughness (micro or macro roughness: skid-resistance or pavement texture depth) and urban intersection safety, all effecting factors about intersection crashes must be considered together or, conversely it can be said that if at selected intersections measured values about affecting factors, excluding skid resistance, are provided as close or same values, it will be possible to identify the relationship between skid resistance and intersection accidents. So, in this study firstly the intersections, whose geometries, approaching speeds and environmental conditions are similar to each other, has been selected.

Then, traffic accident reports were gathered, firstly some geometric and traffic volume measurements were taken from 10 urban signalized intersections in Isparta. Five of these intersections were selected by using the collected data. Microtexture and macrotexture values of these intersections were measured and with probability based approach, it is tried to identify the relationship between skid resistance and intersection crashes.

2. Evaluation of Previous Studies and the Importance of Skid Resistance

At urban road networks, safety characteristics of a pavement is one of the measures of its condition, and in developed countries, highway agencies continually monitor this aspect to insure that roadway sections are operating at the highest possible level of safety. It is an example that the UK skidding policy has been place for the past 40 years and specifies an investigatory level of skid resistance dependant on safety and risk.

A number of devices are used in UK to measure skid resistance. They measure road surfaces using

SCRIM (Sideway-Force Coefficient Routine Investigation Machines), Grip Tester or the pendulum. In a laboratory, skid resistance of the coarse aggregate is assessed using the PSV (polish stone value) test with the Wehner Schulze and Road Test Machine devices currently being assessed to assess asphalt mixes [5].

To obtain accurate results from the studies and to give decision about safety at road urban sections, data must be regular. In previous studies according to this aim, different test methods were used for collecting data. For instance, Woodward et al. [6] considered the development of skid resistance for a SMA (stone mastic asphalt) surface using high PSV (polish stone value test) greywacke aggregate and polymer-modified bitumen. The SMA surface has been periodically measured using a Grip Tester to determine how skid resistance has developed from early life through to mid life. They found that the combination of aggregate and bitumen has a significant effect on skid resistance during the early life of asphalt surfacing materials.

In other studies, locked-wheel trailer methods are used to evaluate skid resistance of highway surfaces according to ASTM E274 procedure. From the measured resistance force, the SN (skid number) is calculated. Another skid resistance evaluation procedure is by the use of the yaw mode system. In this system, the wheels are turned at some angle to the direction of motion. The side or cornering forces are measured and transformed into skid numbers [7].

Fenech [4] conducted a study on the nature of skid resistance, with particular reference to the fundamentals of the tyre-pavement friction mechanism and pavement skid behavior. The study concluded that among the characteristics of the road surface, the micro-roughness has most considerable influence on the skid resistance.

The texture at macro scale is required to remove on a wet road surface, especially at higher vehicle speeds, the water from the contact area between the tyre and

the road surface. The macro texture is determined by the size of the aggregate particles at the road surface. The micro texture is determined by the roughness and angularity of the surface of the aggregate particles. The micro texture ensures the removal of the last traces of water from those locations where high contact pressures between the aggregate and the tire are present [8].

In accordance with ASTM Standard E303 the Portable British Pendulum Tester is also commonly used [7, 9] for micro roughness measurements. The British Pendulum Tester is a dynamic pendulum impact type tester which is based on the energy loss occurring when a rubber slider edge is propelled across a test surface. The values measured are referred to as BPN (British Pendulum (tester) numbers) for flat surfaces, and PSVs for specimens subjected to accelerated polishing.

In a region study, adherence test with Vialit plate, Nicholson stripping test, accelerated polishing test (PSV) were carried out on four aggregate samples which were used in seal coats and hot mix asphalt in Afyonkarahisar City. Results were compared with values of specification limits. The results showed that particularly limestone aggregates polishing stone values were poorer than volcanic aggregates sample. Especially, use of aggregates having a good polishing resistance would be an important factor increasing driving safety [10].

There are some studies about effects of skid resistance on road accidents. Şengöz et. al. [11] would like to evaluate the friction characteristics on the urban roads of Izmir by way of Dynamic Friction Tester as well as build a relationship between the traffic accidents and measured parameters. They found that road surface characteristics and traffic safety improvement works have a great importance on traffic safety.

Most of research results are consistent in indicating that wet pavement conditions significantly increase the number of crashes and statistically significant

negative correlations of skid resistance values and pavement accident rates have been found [12-15].

Nowadays, vehicle speeds have also increased due to the developing technologies. However, surface texture features are not sufficient for those increasing speeds. The interaction between wheel and pavement (tire-pavement interface) is decreasing as a result of the high speeds, moreover, it vanishes during the rainy weather conditions. A study conducted in England produced that improving skid resistance value of the pavement for 10% provided a 13% reduction in traffic accidents occurring in rainy weather [16]. In other words, the number of accident numbers change as a result of the road surface conditions. Xiao et al. [17] have showed that rising of road surface skid resistance value from 35% to 48% makes a 60% decrease in traffic accidents.

Safety analysis studies show that there are many factors that affect pavement surface friction. It is indicated that traffic level, highway class, pavement age and percent of air voids in the asphalt mix have significant effects on pavement friction. Also, wet pavement has an important effect. Pavement skid resistance is reduced as a pavement gets older. In addition to this, when the water film on a pavement is of a certain thickness, vehicles may hydroplane, i.e., the tires may be separated from the pavement by the water wedge formed between the tire surface and the pavement surface. Total hydroplaning occurs when fluid pressure forces (generated as a result of change in momentum of the fluid particles) in the water-wedged region exceed the total downward load on the tire [18].

The study by Ryell et al. [19] reported that the rate of wet accidents (number of wet-weather accidents per 100 million vehicle-miles) increased from about 27 at an average skid number of about 55, to about 75 at an average skid number of about 25. The results of another study [20] reported the significant reduction in the percent of wet-pavement accidents from 78% to 30% due to increasing the pavement coefficient of

friction from 0.20 to 0.45 by applying surface grooving.

Salt [21] concluded that whilst a surface with a friction coefficient of 0.60 and above might by chance be a scene of an accident in which a vehicle skids in wet weather, the risk that it would be the scene of repeated skidding accidents was extremely small. This risk first became measurable with a coefficient of 0.55 to 0.60 and increased sharply by more than 20 times as the coefficient fell to values of 0.40 to 0.45 and by about 300 times when the coefficient was 0.30 to 0.35. A study conducted on the streets of Muscat indicated minimum skid number of 0.45 on normal sites [22]. Another study [23] concluded that pavement with skid number below 26 were very slippery and had to be corrected.

In Saudi Arabia Al-Mansour [24] investigated the effects of pavement skid resistance on traffic accidents. The analysis included establishing relationships between skid resistance and accident number, accident significance and accident density. It was determined that a decreasing skid resistance leads to an increase in traffic accidents. A critical value of skid resistance was also established based on number, significance and density of accidents. As Al-Mansour [24] indicated, there are no standards agreed upon which define minimum acceptable skid resistance levels. Several studies have been conducted to develop criteria for critical skid resistance levels.

In the study of Piyatrapoomi et al. [25], it is again denoted that the number of crashes increases as the skid resistance of a road decreases. Piyatrapoomi et al. [25] added that regression analysis, correlation analysis and other types of analysis methods including one-table or two table analysis methods commonly used methods for assessing the relationship between road crashes and skid resistance [26-29]. These methods provided mixed results and were not conclusive due to the variation in crash data and skid resistance data and Piyatrapoomi et al. [25] structured their study in two parts. The first part presented the results of regression analysis. The results confirmed

the trend that crashes increased when skid resistance decreased. However, the coefficient of correlation (r^2) values were very low. Thus, it is indicated that as it had been found by previous studies, the regression functions could not be provided confidence in the relationship. In the second part of the study, probability-based method was used and the results of a case study showed the relationship between road crashes and skid resistance.

Generally, most of previous studies included only highways that had a uniform roadway width and shoulders. Also, in these studies as segments with intersections had been excluded from the studies. So although the importance of maintaining adequate levels of pavement friction to safeguard road safety is generally accepted, previous research results on the interaction between skid resistance and urban intersection accidents are scarce.

3. Study Objectives

According to previous studies, the principal measure of pavement safety is skid resistance. In developed countries, skid resistance data are collected regularly to evaluate the effectiveness of a pavement in preventing or reducing skid related accidents. However, in developing countries, skid resistance data are not collected regularly especially at urban intersections.

In Turkey, the effect of surface defects are not determined in urban intersections, also are not included in the accident reports or other urban data collection system. Thus, defects caused by road characteristics are ignored while calculating the accident statistics. According to statistical data in Turkey, it is reported that 1% of the accidents occurred due to the defects of the road and environmental conditions. Yet, in other countries defects of the roads and environment cause 20%-30% of the road accidents, also in the US the percentage rises up to 36% [30]. According to Lum and Reagan [31] about 34% of serious crashes had contributing

factors related to the roadway or its environment. This comparison does not show that road geometries or pavement roughness in our country are much better than in developed countries; Conversely, it reveals the deficiencies about skid resistance and other road geometric measurements.

There is a need for skid resistance studies at intersections which are not enough for developing countries like in Turkey. According to this belief, the main objective of this study is to identify the relationship between skid resistance and urban intersection crashes.

The other objectives of this study are as following:

- to determine the importance of collecting pavement surface measurement data for urban signalized intersection;
- to collect micro and macro texture measurements of pavement from selected intersections using British Pendulum Tester and sand patch method;
- to identify the exact locations of the traffic accidents and to match them with pavement skid resistance measurements.

4. Field Study

It is clear that the skid resistance and safety study

Table 1 Intersection details for analysis (crash rates are only for accident occurred legs from selected intersections for five years period).

Intersection name	Leg number	Pavement type	Pavement age (years)	AADT	Crash Rate (number of crashes/per million veh.)
102-160-180 st.	4	Hot-mix asphalt	6	Leg No. 1: 5,760 veh/day Leg No. 2: 3,460 veh/day Leg No. 3: 7,200 veh/day Leg No. 4: 4,608 veh/day Leg No. 1: 5,040 veh/day	Leg No. 1: 1.9 Leg No. 3: 1.52 Leg No. 4: 0.59
102-103 st.	4	Hot-mix asphalt	6	Leg No. 2: 2,520 veh/day Leg No. 3: 6,300 veh/day Leg No. 4: 2,016 veh/day Leg No. 1: 5,440 veh/day	Leg No. 1: 2.17 Leg No. 3: 6.53
154-109-102 st.	4	Hot-mix asphalt	6	Leg No. 2: 2,720 veh/day Leg No. 3: 6,800 veh/day Leg No. 4: 2,176 veh/day Leg No. 1: 3,520 veh/day	Leg No. 1: 2.01 Leg No. 2: 2.01 Leg No. 3: 1.61
105-135 st.	4	Hot-mix asphalt	6	Leg No. 2: 1,760 veh/day Leg No. 3: 4,400 veh/day Leg No. 4: 1,408 veh/day Leg No. 1: 3,650 veh/day	Leg No. 3: 0.96
110-111-129 st.	4	Hot-mix asphalt	6	Leg No. 2: 5,670 veh/day Leg No. 3: 4,900 veh/day Leg No. 4: 2,600 veh/day	Leg No. 1: 0.75 Leg No. 2: 0.48 Leg No. 3: 1.12

analysis would be complicated due to the quantity and complexity of the variables affecting the intersection accidents. Large number of variables play a significant influence on the values of accident rates. One main difficulty encounters in the analysis is that selecting the intersections which must have the same properties, more than one factor is different for most of intersections so direct judgment is further complicated.

In order to achieve the objective, firstly pavement production dates of intersection were obtained from Isparta Municipal Department of Technical Services (shown in Table 1). Also, some remarkable results have been achieved. Information has been obtained for 10 signalized, four leg intersections whose pavement life were same in Isparta.

Other effective parameters such as intersection traffic value, intersection geometries, intersection approaching speeds and control systems were considered and some geometric measurements were taken from the field of 10 signalized intersections. The intersection traffic volumes were measured with hand cameras, and volumes were evaluated, then the horizontal angles measurements of all for legs, the slope values, traffic island and refuge geometries and

approaching speeds were measured. Also environmental conditions of intersections were taken into account. After evaluating measurements, five signalized intersection were selected which have closest measurement values to each other about intersection geometry, approaching speed. Table 1 shows the selected five intersections' characteristics for the analysis. Accidents that have same coordinates for each intersection legs were used for the analysis. Each leg of intersection and their traffic volumes are shown in Table 1 and accident rates were calculated by using Eq. (1). Pline [32] and Koldemir [33] had indicated that this formula could be used for getting accident rates at intersections.

It is important to indicate that selected intersections' capacities are very different each other. It is not possible to find same traffic volumes for each intersection and each leg. To take into account of traffic capacities in five selected intersections, instead of accident numbers, accident rates are used with the help of Eq. (1). Then it became possible to investigate pavement roughness with considering traffic volumes.

$$AR = (AN \times 10^6) / (AADT \times 365) \quad (1)$$

where, AR , AN and $AADT$ are accident ratio (for million vehicle), annual accident number and annual average daily traffic, respectively.

Traffic accident reports are gathered from City of Isparta Traffic Control Branch Office for five years (2007-2011) and selected intersection accidents were investigated. The types of accidents are fatal, injury and property damage. According to accident reports, the coordinates of accident locations are found. Then the locations of each accident were determined at the selected intersection legs from the accident records.

Generally, recent studies are based on data from a specific road network of the country where the study is performed. The data parameters have been used from international reference. Also, in most published research results refer to the two most common skid resistance measurements: SN and SCRIM [15]. One

of the most popular procedures which are used to evaluate the friction resistance of the road surfaces is the Portable British Pendulum Tester. It gives values in SN (Skid Number) and measures in accordance with ASTM Method E-303. The BPT (British pendulum tester) is a dynamic pendulum impact type tester which is based on the energy loss occurring when a rubber slider edge is propelled across a test surface. While micro roughness of pavement surface texture is measured with BPT, macro roughness of texture is measured using the Sand Patch Method in accordance with ASTM Method E-956 [34] for selected intersection.

Fig. 1 is an example of photos taken while getting measurements. Although in selected intersection legs' pavement ages were same, measured texture values were very different. It is mostly because of the traffic capacities on the intersection legs and shows again the important effect of intersection traffic volume on safety measures. Traffic volume not only directly affects on intersection safety but also affects the pavement texture and to traffic accidents as well. Because of this while analyzing the results, instead of accident numbers, accident rates (accident no per vehicle) have been used.

5. Research Methodology and Analysis

The objective of this study is identifying the relationship between skid resistance and urban intersection crashes. A probability-based method is used for explaining the relation about skid resistance. This method was firstly used by Piyatrapoomi et al. [25] for identifying relationship between skid resistance and road crashes, it was used for a road length of approximately 169.9 km. But they had not used this method for intersections. In this study, probability-based method is used only for urban signalized intersections differently from the study of Piyatrapoomi et al. [25].

For identifying the relationship between road crashes and skid resistance, firstly a common method



Fig. 1 An example of photos taken while getting measurements.

(i.e., regression analysis) is performed. The result of the regression analysis is shown in Fig. 2. This approach has been performed between micro texture measurements (SN values) and intersection accident rate for each leg of selected five signalized intersections which have closest measurement values to each other about intersection geometry and approaching speed. Fig. 2 shows the plots of relationship between intersection crashes occurred on intersection legs for 2007 to 2011 and measured skid resistance values.

In Fig. 2, regression line shows that there is a trend while the skid resistance decreases intersection accidents increase for these five year periods. But, low (r^2) values indicated that there is a high variation in the crashes and pavement roughness data and the relationship between road crashes and pavement roughness cannot show conclusions with confidence, just like the study of Piyatrapoomi et al. [25] as it was told in previous studies Part 2.

After getting this unsatisfactory result, an analysis technique based on probability theory is used. In this analysis, five selected signalized intersections which have very close properties used again, to ensure that

the pavement roughness data can be described by probability distribution.

As it is known it is often helpful to look at probability distribution in graphic form. Instead of probability histogram, in order to interpret effectively, CDF (cumulative distribution function) is used. In probability theory and statistics, CDF describes the probability that a real-valued random variable X with a given probability distribution will be found at a value less than or equal to x as shown in Eq. (2). The cumulative distribution function completely describes the probability distribution of a real-valued random variable, X [35]. For every real number x , the CDF is given by:

$$F(x) = P(X \leq x) \quad (2)$$

where, the right-hand side represents the probability that the random variable X takes on a value less than or equal to x . The cumulative distribution is a non-parametric distribution with a wide variety of applications [25, 36] and it is very useful to model an expert's opinion of a variable whose range covers several orders of magnitude in some sort of exponential way, for example, the size of impact on insurers of a large earthquake, the financial impact of

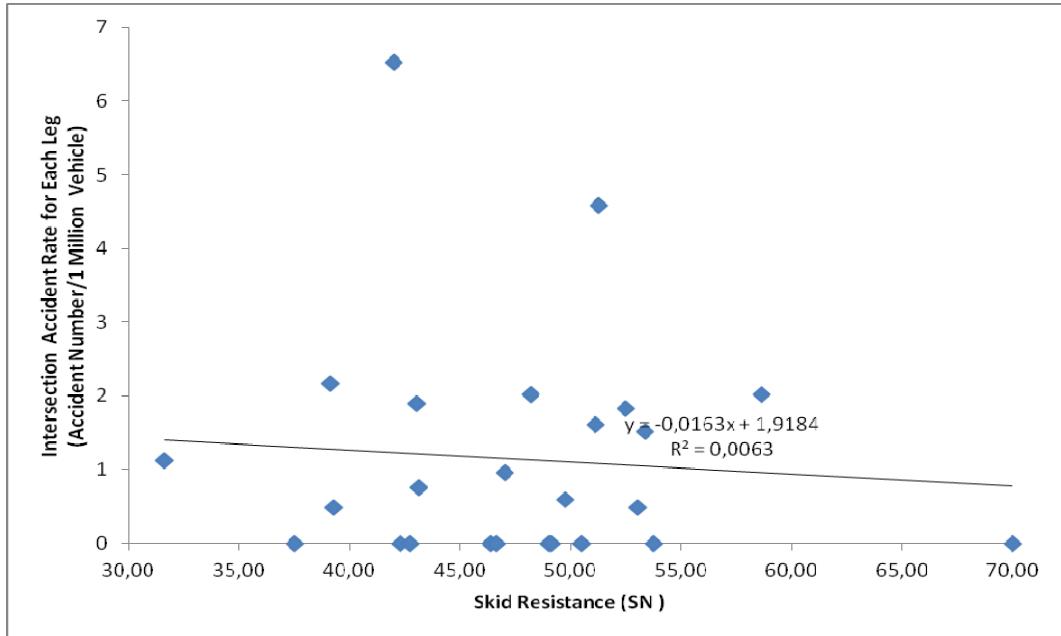


Fig. 2 Relationship between intersection accidents and skid resistance for selected signalized intersections in City of Isparta.

a market crash, or some other extremal event for which that are no relevant data with which to estimate the variable. In such circumstances, it is fruitless to attempt to use a relative distribution directly [37].

Consequently, with this technique it is aimed to assess the degree of variation of skid resistance at intersection legs and assessing this variation characteristic with intersection crashes. So the cumulative probability distribution of five signalized intersections (only accident occurred at legs are selected) for five years, skid resistance data and texture depth values are shown in Figs. 3 and 4.

Variability of skid resistance for each intersection leg is quantified. Then the cumulative probability distributions of accident rates for skid resistance data are showed in Fig. 3. In the light of Fig. 3, acceptable percentage of crash rates can be expounded and can identified the probability distributions of skid resistance. For example, when the skid resistance number is 53.5, probability of accident occurrence rate shall be 15%. Also, while skid resistance number is 38, probability of accident occurrence will be 85%. A thorough analysis can be conducted using the probability distribution method in assessing the

characteristics of cumulative probability distribution of skid resistance and crash risk for different site conditions of intersection approach. Because the results of the analysis show similarities with the previous studies like the study of Ryell et al. [19] that was given in Part 2.

As it is known from the previous studies, macro scale is required to remove on a wet road surface, the water from the contact area between the tyre and the road surface. So it does not directly affect on intersection safety but it affects on pavement friction. Also, friction can be important for intersection approaching speeds. So same analysis was carried out as in Fig. 4 for texture depth data which were gathered from sand patch measurements, and realistic results were gathered. For example, when the average texture depth is 0.75 mm, probability of accident occurrence rate shall be 15%. Also, while texture depth is approximately 0.50 mm, probability of accident occurrence will be 85%.

6. Conclusions and Recommendations

To detect the same type intersections, the number of intersections was selected limited. It was difficult

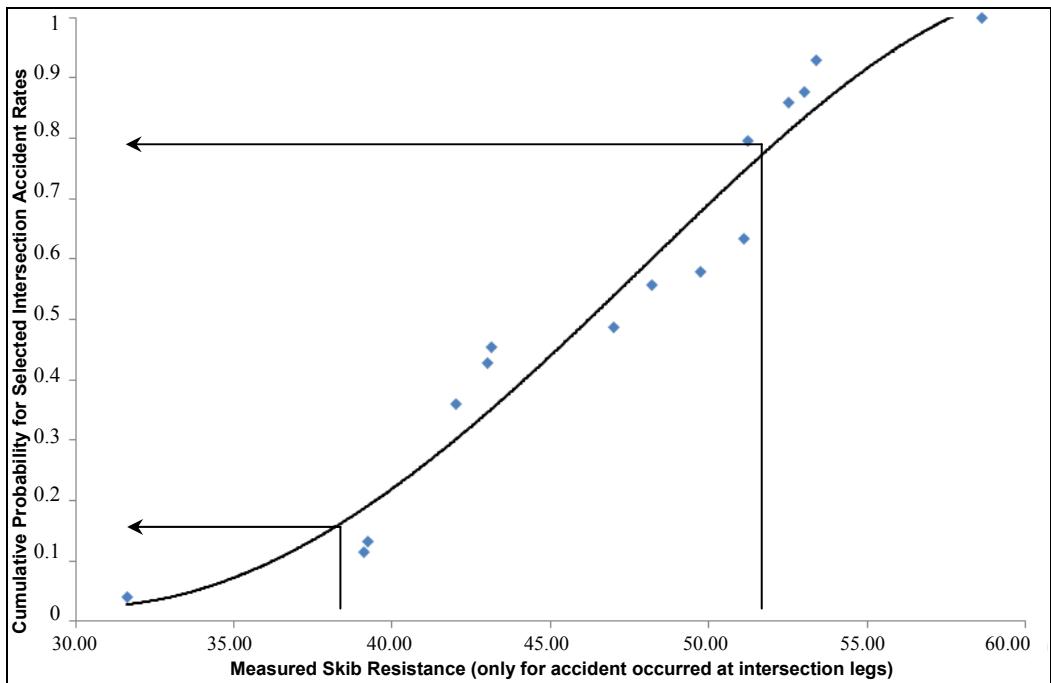


Fig. 3 Cumulative probability distributions of measured skid resistance at accident occurred at intersection legs.

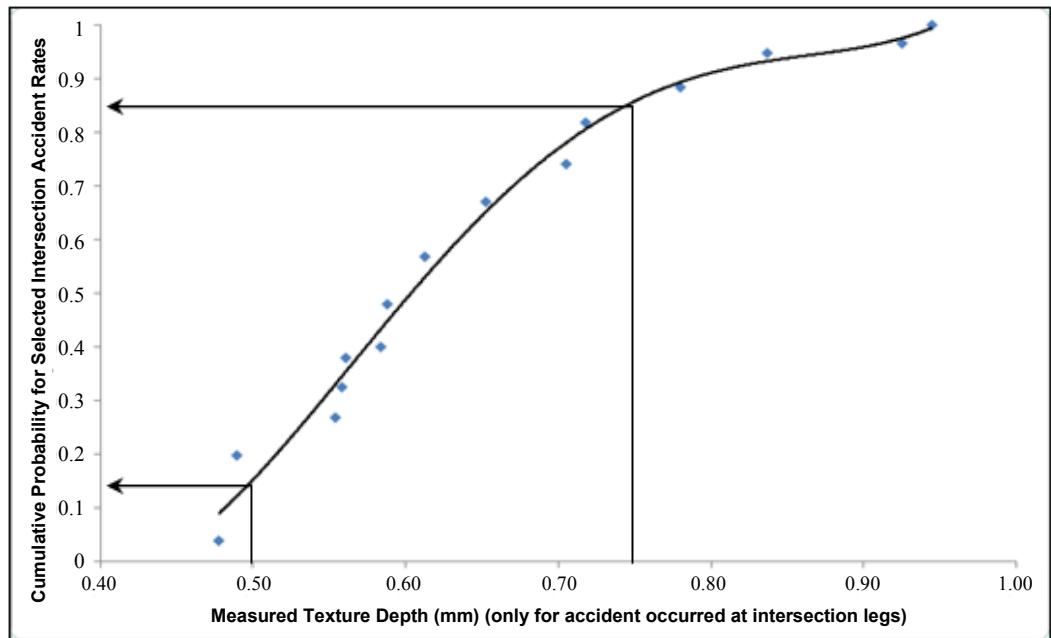


Fig. 4 Cumulative probability distributions of measured texture depth at accident occurred at intersection legs.

to find intersections whose features are same. Despite of this, five signalized four leg intersections which have very close properties were selected. The investigation of the effect of roughness on traffic safety at these urban intersections was performed. When the regression analysis is performed between

road crashes and skid resistance, unsatisfactory results are gathered. So an analysis technique based on probability theory has been used. This method is used for expounding the interaction between skid resistance-intersection and accident rates. For example, when the skid resistance number is 53.5, probability

of accident occurrence rate shall be 15% and when the skid resistance number is 38, probability of accident occurrence will be 85% (Fig. 3). Same analysis is carried out for texture depth data as shown in Fig. 4 and results are gathered. For example, when the average texture depth is 0.75 mm, probability of accident occurrence rate shall be 15%. Also, while texture depth is approximately 0.50 mm, probability of accident occurrence will be 85%. With these results, it is indicated that collecting pavement measurement data is very necessary for urban intersections.

In this study, skid resistance values were investigated for evaluating the signalized intersection accidents. Other factors which are effective on intersection accidents are tried to eliminate by selecting same type intersections. So the intersection data were limited.

Being the first study to be carried out locally about signalized intersections and skid resistance in City of Isparta, it is recommended that further skid resistance measurements for the sites can be carried out so as to verify the trends and conclusions accomplished in this study, especially considering with different type of intersections and all intersection effecting parameters together.

Data can be expanded with different pavement combinations. Because after the study results are evaluated, it is understood that pavement roughness is very important for urban intersection safety measures. Different mix performance of different type of pavement can be found for more safe intersections for future works.

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Cloud Computing Applications in Global Logistics

Information System Infrastructure

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Abstract: Information and communication technology (ICT) and systems are essential for every business. They can be used in retail, manufacturing and other industries. Nevertheless, new and innovative ideas and solutions are constantly emerging and introducing new possibilities for the reorganization of traditional logistics processes. Particularly, attention is given to basic concept of CC (cloud computing) service models and opportunities in logistics. This paper provides comprehensive review and comparison of different ICT solutions and CC applications. As a new and cutting-edge technology, CC is changing the form and function of information technology infrastructures making supply chain information collaboration easy and feasible. It can also be an enabler of fully electronic logistics management systems. Adoption of CC concept involves strong hardware support, good internet connectivity and implied reorganization of traditional business activities.

Key words: Cloud computing, information and communication technology, logistics, supply chain, service models.

1. Introduction

Information technology systems and applications are essential to businesses and enterprises. In the last two decades, ICT (information and communication technology) has strongly influenced organizational processes and logistics as well. IT (information technology) service is an interconnected set of hardware and software resources, and is conceptually similar to a manufacture or retail supply chain.

Supply chains generally have two functions: a physical function—the production of a particular product and transportation of all components to the right place at the right time; a market mediation function—to ensure that the product meets market needs.

In general, logistics involves a multitude of suppliers, manufacturers, carriers, 3PLs (third logistics partners), 4PLs (fourth logistics partners) and financial institutions that are essential to transporting

a product from place of origin into customer's hands. A study of cloud information technology suggests each of these partners owns a portion of the data that drives the logistics process, and each has a stake in the successful delivery of goods to the final location [1]. A supply chain must be classified according to its components and the end-product it supplies.

As a new business model, CC (cloud computing) has and will have a profound impact on the entire IT industry [2]. CC is offering competitive advantages to companies through flexible and scalable access to computing resources. For a business to successfully utilise the cloud, it needs to migrate some or all of its IT services to the cloud, and then manage the new environment. The undertaken research has shown that, by using a cloud lifecycle, both the migration and the on-going management of the cloud can be planned and controlled to ensure success [2].

Global view, transparency of each phase during realization of logistics processes and comprehensive control over the crucial data are imposed as a priority in contemporary logistics. ICT provides support for logistics processes and solves many logistics problems.

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Constant progress of ICT field brings different solutions for dealing with problems that are emerging in logistics, and for growing customer's demands. CC is among the most-discussed new technologies, and the current reality is that approximately 20% of discrete, process, retail and wholesale manufacturers are using it. In practice, CC enables the uploading, normalization and embedding of data from each participant into the network where they can be accessed if permitted [3].

The traditional ICT approach provides solutions only for specific logistics jobs for which it is installed. In comparison with the CC approach, the old way of doing business is costly, time-consuming and error-prone. Modern cloud-based logistics offers lower costs and collaboration within the network where every new user in the network expands the list of potential partners in virtual supply chain making its connections and data available to all.

The rest of the paper is organized in the following way: Section 2 provides related work in ICT and logistics. Section 3 presents advantages and disadvantages of ICT applications in logistics. In Section 4, concept of cloud computing is presented and followed by detail description of basic characteristics, service models and deployment models. Data quality in the cloud approach and benefits of CC in logistics are presented in Section 5. Finally, Section 6 gives concluding remarks.

2. Related Work

Implementing different kinds of ICT into logistics management can successfully improve and redesign logistics system as a whole, and it can also change customer's view on logistics [4]. ICT implementation and application require the great investment, thorough training sessions and constant learning. There are various ICT solutions for different logistics segments on the market, and the most often used solutions in logistics processes are: APS (advanced planning and scheduling), ERP (enterprises resources planning),

EDI (electronic data interchange), TMS (transportation management system), WMS (warehouse management system), RFID (radio frequency identification), GSM (global system for mobile) communications, GPS (global positioning system), GIS (geographic information system) and Wi-Fi (wireless fidelity).

RFID has strategic importance in empirical and conceptual insights in logistics activities [5]. The impact of RFID technologies on supply chain management is presented in detail in literature [6].

APS systems are improving the integration of materials and capacity planning using constraint-based planning and optimisation in SCM (supply chain management) which can be defined as a process for designing, developing, optimising and managing the internal and external components [7].

Additionally, the impacts of the integrated logistics systems on electronic commerce and enterprise resource planning systems are described in [8].

Intelligent transportation systems are discussed in the study of WMS (Tompkins Associates) which also proposes their applications in integrated information systems [9].

The distribution flow of aluminum alloy pipes, starting with the completion of the manufacturing process and final inspection, considers the use of bar-coded caps integrated in production, transport and customer data bases [10]. The observed process may be improved by cloud logistics system.

The role of geographical information in logistics network management is all too evident. More than 80% of business data have a geographical element, and hence GISs (geographical information systems) are playing an increasingly important role in any area of business. New logistics network which consists of suppliers, warehouses, distribution centres, retail outlets, raw materials, work-in-process inventory, and finished goods that flow between the different facilities which are a part of the logistics network is proposed [11]. Logistics network in web-based GIS-T

system is proposed as well. It presents a basis for CC network adoption [11].

Furthermore, implementation of GSM communications, GPS and Wi-Fi as widely implemented up to date in logistics information systems are discussed in Refs. [12, 13].

3. ICT Applications in Logistics

The ideal production is considered to be the real machine of non-stop working at the maximum speed. The assembly process information flow in real time, enterprise wide, from assembly station sensors to the company policy maker's offices, is the true solution for improving productivity competence, reducing bottlenecks and optimizing the supply chain network. In such a way, missing operations in the floor process are identified and are reducing losses and making greater profits than ever. Business process reengineering and processes transformation are necessary to ride the expected tide of change in the current manufacturing environment, particularly in the information technology and automation landscape.

Benefits of ICT applications in logistics are:

- EDI—reduces bureaucracy, streamlining and logistics costs;
- E-commerce—reduces prices, increases investments, facilitates marketing decisions, enables safety rules;
- APS—reduces costs, improves product margins, lowers inventories and increases manufacturing throughput;
- ERP—improves productivity and transparency, integrates strategies and operations, reduces costs and risks, enables immediate access to enterprise information, improves financial management and corporate governance;
- TMS—facilitates tasks as transportation planning, performance measurement, control over vehicle loading and management of routes, distances and freight payments;

- WMS—manages and optimizes operational and administrative activities along the warehousing process, which involves receiving, inspecting, labelling, storing, sorting, packing, loading, shipping, issuing documents and managing inventory;
- Barcode and RFID—supports various logistics activities, such as picking, vehicle loading and unloading, orders tracking and optimization of distribution routes;
- GSM—supports maintenance of connections between subjects in logistics processes;
- GPS—supports routing and tracking;
- GIS—enables visualization of key processes, high level of interoperability and data sharing, and provides comprehensive approach regarding logistics system as whole;
- Wi-Fi—offers possibility to exchange data wirelessly across logistics complex and establish high speed internet, improve safety and security in logistics network.

ICT applications in logistics are investigated and sorted, as well as:

- ICT systems and business process incompatibility;
- collaboration problems with partners, customers, and consumers;
- the high fixed cost of ICT;
- limited resources available to solve problems;
- lack of data quality and consistency;
- lack of access to systems and information;
- lack of speed of implementation;
- lack of transparency;
- lack of a comprehensive view of the business;
- inability to easily and quickly acquire new capabilities [2].

Multinational companies strive to reduce computing costs, to improve plant floor visibility and achieve more efficient business power of their IT hardware and software investments.

4. Concept of Cloud Computing

CC shifts the frontier of ICT possibilities in modern

business. Different complex software solutions and applications for business become available online and CC leads to this new trend. CC infrastructure accelerates and promotes these objectives by providing unparalleled flexible and dynamic IT resource collection.

4.1 Basic Characteristics

CC experts and administrators maintain, update and upgrade all the applications that each client requires. All the clients are, simultaneously, a part of a complex virtual network, which facilitates their business organization, because all the partners are constantly interconnected. What is important to stress is that time can be saved, efficiency increased and high quality data achieved. By adopting cloud solutions, an organization can focus on their core business, as cloud providers are under obligation to run ICT applications faster and more cost-efficiently.

CC characteristics are:

- on-demand self-service;
- broad network access;
- resource pooling;
- rapid elasticity;
- measured service [14].

Benefits of CC adoption as new business concept are:

- cost containment;

- innovation speed;
- availability;
- scalability;
- efficiency;
- elasticity [15].

4.2 Service Models

Service models define what kind of services can be provided from the cloud. Depending on the chosen model, the provider offers and delivers different services. Three main service models are illustrated in Fig. 1. There are:

- (1) IaaS (infrastructure as a service);
- (2) PaaS (platform as a service);
- (3) SaaS (software as a service).

Nomenclatures of presented layers in Fig. 1 are:

- Infrastructure—a physical layer (servers, processors, storage devices, network);
- Hypervisor—a virtualization layer which provides the virtualized infrastructure resources;
- OS—the operating system which provides the system resources;
- Middleware—supporting software for communication between upper and lower layers;
- Runtime—special environment in which the chosen application is executed;
- Applications—different applications offered to clients.

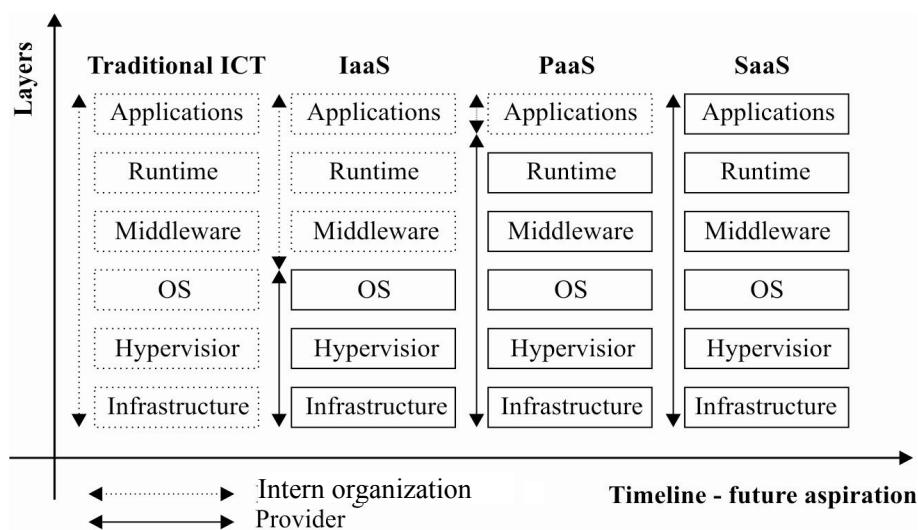


Fig. 1 Service models [14].

IaaS is a platform through which businesses can avail itself with equipment in the form of hardware, servers, storage space, etc. at pay-per-use service. In this service model, cloud providers offer everything from physical or virtual machines to raw storage, firewalls, load balancers and networks [14]. More specifically, the user buys these resources as a fully outsourced service instead of buying servers, software and network equipment as discussed in Ref. [16].

In PaaS, cloud providers host a computing environment typically including operating system, data base and programming language execution environment, where users develop and deploy applications. Users can rent virtualized servers for running existing applications or developing new ones without the cost and complexity of buying and managing the relating hardware and software [16].

In SaaS model, cloud providers install and operate application software in the cloud and users access the software through various client devices through either a thin client interface, such as web browser or a program interface. The cloud users do not manage the cloud infrastructure and platform on which the application is running but have control over the

deployed applications and possibly configuration settings for the application-hosting environment [14].

The new service models with new IT paradigm are presented in Fig. 2. The former theoretical model is extended and reshaped [17].

New defined model ITaaS (IT-as-a-service) is sometimes called BPaaS (business process as a service). This service type combines the application elements of CC with human aspect. The main difference between this service and traditional IT outsourcing is the fact that the human resources providing the ITaaS are as well pooled between different clients.

Each of these service models can be used more than once in the cloud supply chain. And these not only provide single services but can also be combined to provide value-adding services that act as single objects in the cloud supply chain. These aggregated services can be made up of two or more services, e.g., infrastructure and platform can be combined as a service for software developers.

4.3 Deployment Models

CC can be run in various deployment models which

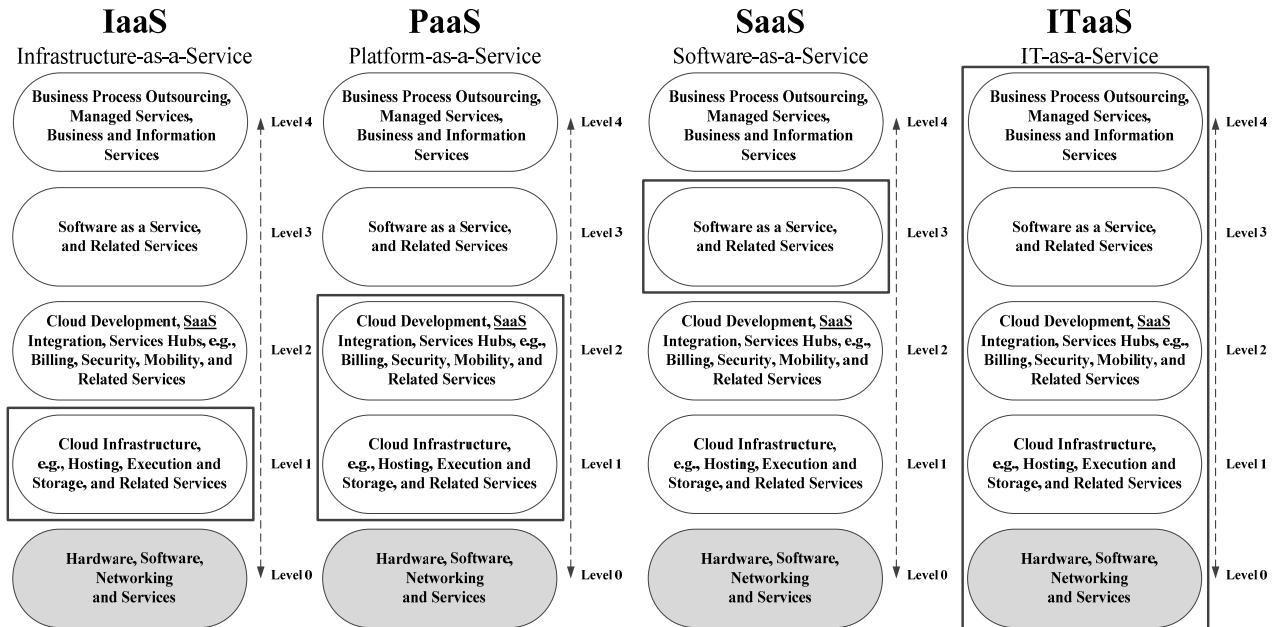


Fig. 2 Service models with new IT paradigm [17].

will be used depending on the user requirements and on market availability [15]. There are various divisions, but according to authors, five deployment models can be differed (Fig. 3).

On-Premise cloud—all services are provided to the client's premises usually by a third-party provider.

Private cloud—the service is used by private clients. A private cloud can be run internally by a provider.

Community cloud—the service is used by several members of a defined group. The services may be offered by several providers who are either internal or external to the community.

Public cloud—the service is available to the public and in general provided by a single provider.

Network cloud—offers a combination of various organization forms, combining their respective advantages and disadvantages.

5. Opportunities of Cloud Computing in Logistics

Logistics resources and web services are two major aspects of cloud oriented logistics. Logistics resources are characterized by variability, geographical distribution, heterogeneity, morphological diversity and self-governing zone. Web services are proposed as characterized by distribution and heterogeneity in a

cloud logistics platform [19].

Integrated into complexity of cloud network, logistics resources present a platform for the virtualization of information and material flows. Therefore, reorganization of traditional logistics is imposed as a priority [20]. CC allows scaling autonomous logistics applications flexibly based on the dynamically arising logistics demands. The main goal is to facilitate smooth realization of individual and complex logistics services.

5.1 Data Quality in the Cloud Approach

In logistics, the correct information is essential in order to efficiently realize any process. When introducing modern technologies and various software solutions into logistics branch, significance of the correct information becomes priority. High quality data are crucial because every software solution (especially CC) requires quality input values in order to provide quality output values. If data are incomplete or incorrect, the most of advanced software systems are useless when it comes to decision-making. High quality data must be complete, accurate and with accurately determined time frame.

There are three steps for getting quality logistics data in traditional ICT network:

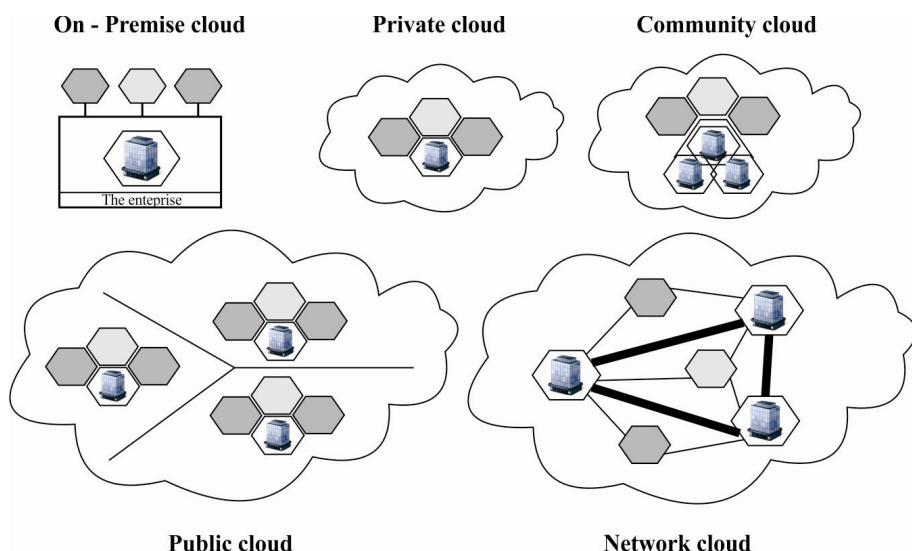


Fig. 3 Deployment models [18].

(1) Connecting with partners: (a) building an ICT infrastructure, (b) determining communication protocols (EDI) (Fig. 3);

(2) Normalizing the data they provide: (a) monitoring data flow—dedicated ICT staff, (b) ensuring that the data are normalized (locations, currencies, equipment types, organization names, reference codes, charge codes)—the goal is to avoid confusion;

(3) Managing data quality: (a) monitoring for accuracy, completeness, and timeliness, (b) efficient ICT team of experts that are able to manage the relationships with partners and to provide missing information [21].

As opposed to that, CC offers easier way to establish efficient and effective logistics process which significantly lowers costs and enables time savings. Cloud platform facilitates an on-demand data network.

The basic principle of functioning of such a network is the following rules: the more clients join the network, the lower it costs. The administrators create and maintain the cloud network and update all the information and crucial data across the network which always offers only actual and topical data to clients. Also, cloud network provides data that are already normalized, reduces time-to-benefit and shifts the hassle and technology risk from client-side to the on-demand network provider (Figs. 4 and 5).

5.2 Benefits of Cloud Computing in Logistics

The impact of CC in logistics is visible in three important segments:

(1) Collaboration—in each logistics process there is a large and variable number of participants which is why the collaboration between all the entities can be inefficient and even poor. Lack of cooperation between participants and barriers between different ICT solutions in each company are the main reason for emphasizing CC as new form of doing business in logistics. CC offers a common platform for all entities

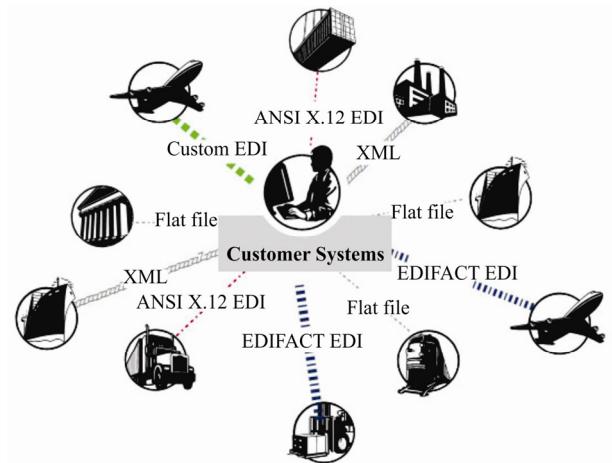


Fig. 4 The traditional ICT data network [21].

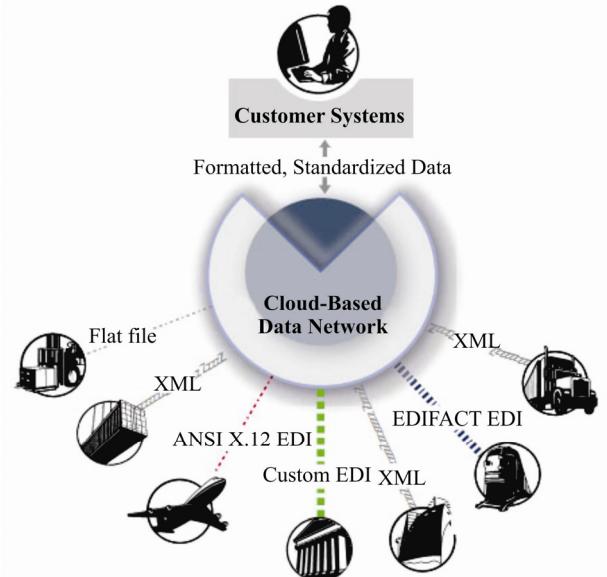


Fig. 5 The cloud data network [21].

in logistics processes making them interconnected in the network;

(2) Modernization—volatility and the unpredictable nature of modern logistics processes encourage the transformation of the traditional logistics organization. The current trend in business is that the most of logistics processes have variable rather than fixed costs. Therefore, CC provides modernization and enhancement of logistics organization and makes logistics processes more transparent and subject to data quality forecast which later facilitates decision-making process. Unique database and centralized ICT system decrease errors in business,

increase operations efficiency and enhance realization of complete business tasks. Consequently, the need for repeated operations is decreased, customer's satisfaction is improved and financial flows are more balanced and transparent;

(3) Implementation speed—the most important prerequisite for the CC adoption is wide bandwidth and reliable internet connection. Then, the implementation speed of CC is very high. The most important factor is to form a coherent team of experts from logistics and software fields and to suffuse their cooperation.

Benefits and opportunities from the cloud computing adoption in logistics are:

- significant improvements in efficiency;
- increased benefits from faster time-to-value realization;
- single source of a logistics process;
- transparency in communication of all participants in the logistics cloud;
- comprehensive oversight of all processes;
- wide range of solutions;
- tutorials availability—ease of use of applications;
- different analysis of the high quality data;
- time savings when searching the right information and adequate solution;
- visualization of the entire workflow;
- clarity of key functionality;
- various solutions for the same problem;
- updated and upgraded applications;
- constant new emerging capabilities;
- data security.

6. Conclusions

ICT unambiguously provides strategic advantages in business enterprises. Logistics processes without ICT would be insufficient, even impossible, for logistics sector operation. Nevertheless, the constant improvement of ICT sector frequently offers better solutions, but, at the same time it offers new adoption and reorganization of current business politics.

At this moment, cloud computing presents a peak of the ICT impact on logistics. Material flows cannot be transformed significantly by this system, but cloud approach facilitates and improves its realization. Starting with the electronic logistics, an ICT supported logistics, the aim is a new concept which integrates modern technologies, latest software solutions, and high-quality data within a single network.

It also reshapes traditional information flows in which the quality data become available within few seconds.

Cloud computing applications in global logistics information system infrastructure are the most important research and implementation approaches in contemporary enterprise development.

Acknowledgments

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Application of Value Engineering in Construction Projects

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Abstract: The current economic conditions have entailed the use of rational method and techniques and research and application of new techniques by utilizing advancements in technology in the field of production as well as in every field. Excess cost control requires to be maintained throughout the project life of building beginning from the initial stages of design. Scrutinizing the project well and considering all possible alternatives particularly in design stage are important for achieving optimum cost. In this study, how the principles of VE (value engineering) are applied in construction projects is explained, and by covering Bregana-Zagreb-Dubrovnik Motorway construction in Croatia by BECHTEL – ENKA joint venture as the sample project, practices of VE in this project are described. The satisfactory results of time and cost saving are achieved by applying value engineering principles through the VE team during the project preparation phase and project revision phase. Approximately 43,000,000\$ and 12 months of time were saved in total thanks to all these VE works. This saving provided builder company with 6% financial saving and 17% work time reduction.

Key words: Value engineering, value management, motorway construction.

1. Introduction

VE (value engineering) was developed at General Electric Corp. during World War II and is widely used in industry and government, particularly in areas such as defense, transportation, construction and healthcare. VE is an effective technique for reducing costs, increasing productivity and improving quality. It can be applied to hardware and software; development, production and manufacturing; specifications, standards, contract requirements and other acquisition program documentation; and facilities design and construction. VE is defined as “an analysis of the functions of a program, project, system, product, item of equipment, building, facility, service or supply of an executive agency, performed by qualified agency or contractor personnel, directed at improving performance, reliability, quality, safety and life cycle costs”. It may be successfully introduced at any point in the life-cycle of products, systems, or procedures.

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VE is a technique directed toward analyzing the functions of an item or process to determine “best value”, or the best relationship between worth and cost. In other words, “best value” is represented by an item or process that consistently performs the required basic function and has the lowest life-cycle cost. In this context, the application of VE in facilities construction can yield a better value when construction is approached in a manner that incorporates environmentally-sound and energy-efficient practices and materials.

Because “costs” are measurable, “cost reduction” is often thought of as the sole criterion for a VE application and indeed it is primarily addressed in this document. However, the real objective of VE is “value improvement” and that may not result in an immediate cost reduction [1].

VE is a systematic, low-cost approach to assessing the “value” of a project. Typically, VE on projects can be used to gain the following benefits [2]:

- cost reductions;
- time savings (schedule savings);

- quality improvements;
- isolation of design deficiencies.

The paper of Kemmochi and Koizumi [3] demonstrates that aspects and issues of VE in construction industry by comparing with manufacturing industry and combating these, VE implemented in construction industry must be succinct and propose methods to conduct VE from the viewpoint of construction industry. In a study prepared by Naderpajouh and Afshar [4], a conceptual expert CBR (case-based reasoning) framework is introduced in the paper to form a coherent basis for the provision of practically suitable VE expert models. The proposed framework outlines knowledge entities and their relations in the VE workshop. The model benefits from a fuzzy approach to handle uncertainties in the evaluation phase of the methodology. In the another study, focusing on one component of the ICD (integrated collaborative design) project, the paper reviews existing, reactive value engineering methods and establishes the need for an integrated approach by identifying their inadequacies. A value management context is described which integrates value engineering into continuous design processes. The paper discusses the opportunities for utilizing supplier design expertise by modelling design process information flows [5]. The paper prepared by Palmer and other [6] makes a holistic appraisal of value engineering as used in the United States of America's construction industry by investigating current theory and practice. It evaluates value engineering projects and calculates the savings achieved by them. Omigbodun's paper examines how value engineering contributes to the process of obtaining an optimal solution to the design problem of a building project [7]. Cost minimization in building construction is discussed with examples from the writer's experience on building projects in West Africa and the Middle East.

VE is not cost cutting. VE is a systematic method to improve the "value" of goods or products and services

by using an examination of function [8]. Value, as defined, is the ratio of function to cost (Eq. (1)). Value can, therefore, be increased by either improving the function or reducing the cost.

$$\text{Value} = \frac{\text{Function (desired performance)}}{\text{Overall costs}} \quad (1)$$

Reasons for poor value can be that: lack of information, decisions based on wrong beliefs, habitual thinking, negative attitudes, reluctance to seek advice, shortage of time, changing technology, lack of a yardstick for measuring value, old specifications and poor human relations.

Value engineering gets closer to cost control because it looks at ways to reduce costs on specific items or activities. However, it does not look at the total project picture or check the daily performance, it focuses only on specific items in the design, procurement or construction area.

2. Methodology and Approach

VE Job Plan consists of the following sequential phases (Fig. 1).

The value methodology is a systematic process following the Job Plan [2] and is applied by a multidisciplinary team to improve the value of a project through the analysis of functions.

The team leader should have completed at least a 40-hour VE training study and should have additional VE experience as a team member of VE Project studies. Other team members should have attended a one-day VE orientation course prior to being assigned to a team, or alternatively the study may start with a planned one-day VE orientation [9].

3. When to Apply Value Engineering

VE should be performed as early as possible—before commitment of funds approval of systems, services, or design—to maximize results [8]. Contribution of potential savings from VE applications is much greater at earlier stages of a project, as illustrated in Fig. 2. When VE is applied

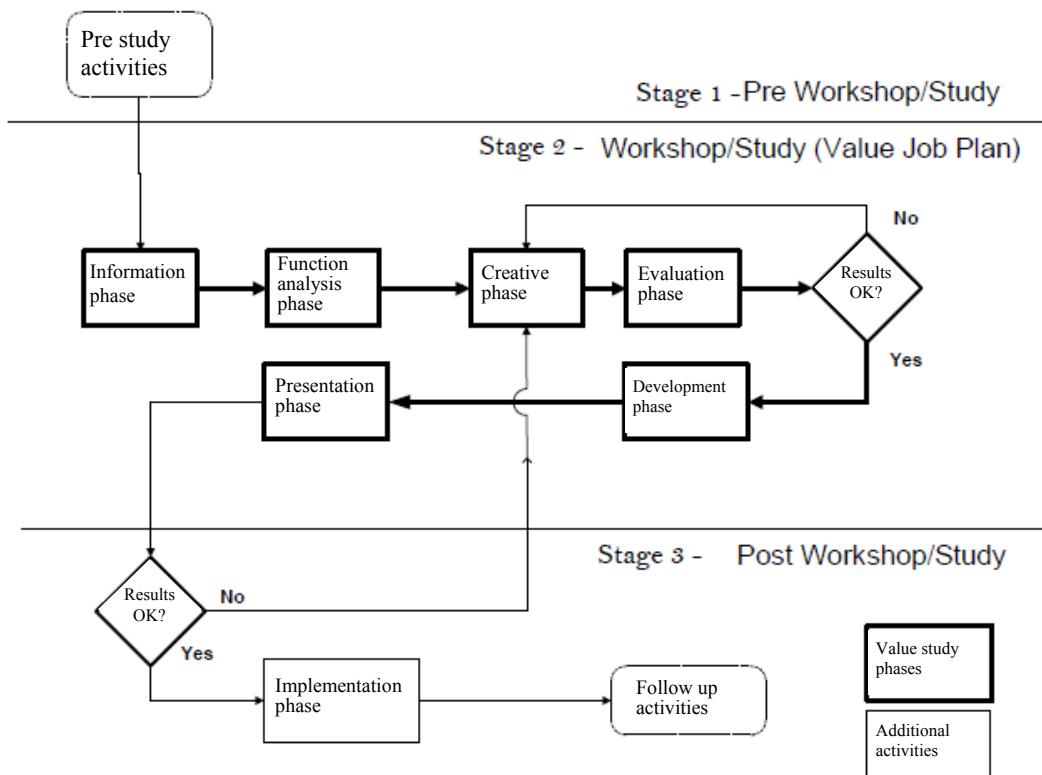


Fig. 1 The job plan [2].

later, two things increase: the investment required to implement any changes and resistance to changes.

VE is neither just good engineering, nor a suggestion programme, nor a routine project or plan review; it is carried out in independent analysis of the project. It must be recognized that VE entails a certain amount of additional expense that must be justified by potential cost saving. Accordingly, the need for a change in criteria, concepts, or plans must be recognized. A distinct opportunity for financial rewards in terms of life-cycle cost savings must warrant the added project engineering cost of a VE effort.

4. Usage of VE in Construction Sector

Companies in the construction sector have a better chance of getting jobs when they use the resources of the country in which they work reasonably, keep their costs at the lowest level and decrease their offer price in comparison with their rivals [10]. But the low offer price is not the only factor for a specific company to

get the job. Project must have a high “value”. Value has different meanings for the producing company, owner, user or the designer. The builder company tries to finish the construction with the lowest cost to obtain high profit. Owner wants to get the biggest income from the building. User wants to be able to perform his works easily, while the designer gives more importance to his creation’s aesthetics or functions.

Purpose, time, quality and cost of every activity that will be realized during the construction process must be determined or estimated beforehand. Owner or user wants to know which feature they will have after the building is completed and with what cost they will have it.

Because construction process has many components such as concept, design and drawing details of the project, construction etc., and it is a long-term production, the risk of completion of construction in time, based on the estimated costs (first investment + usage cost) by providing features

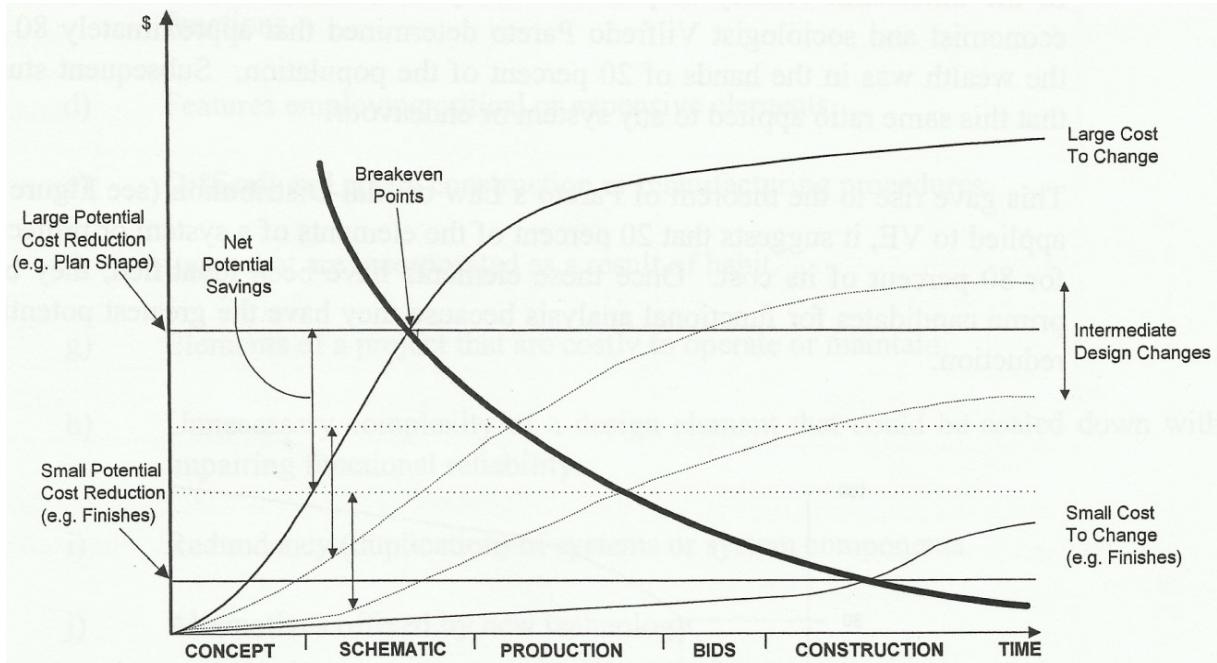


Fig. 2 Potential savings from VE applications [9].

such as quality, durability, usefulness, continuity, feasibility, compliance, image and management convenience, increases.

Suitable precautions are taken by predetermination of problematic areas via various project plannings and scheduling techniques. But none of these methods includes an examination in terms of the “value”. After a building is completed or during the construction stage, comparing the building value with the costs that occur during its construction is not thought about. Although many buildings were built with high costs, desired functions were not provided. There is absolutely no direct proportion between a building’s costs and provided benefits. In value engineering rationalist evaluation techniques are used considering the target features, and unnecessary costs are determined to be eliminated from the project, so that a building’s value is increased and resources (money, material and workforce) are not wasted.

Some methods that increase the value in construction sector are explained as follows.

4.1 Reducing Construction Production Costs

In constructions, especially in functions with high

production costs, the costs can be reduced without sacrificing construction’s quality or disregarding customer’s requests, by using different materials and/or different methods.

Materials, equipments and stipulated production methods in the specification and projects may become old according to current day or be out of date. In case the suggestion of the contractor for making changes is accepted by the employer, a much more economical solution will be provided for both sides. Carrying out production with better quality by using the suggested methods, in other words improving the quality may be a more economical solution [11].

4.2 Finishing the Job before Time Schedule

Finishing the job earlier provides economical benefits in term of reducing general costs. By comparing the cost of job acceleration and the reduced general costs, it can be decided to complete the job earlier.

It may not be necessary to accelerate the production speed to finish a job earlier. It may be possible to start earlier.

For such a condition to exist, these conditions may

be considered to happen:

- finishing the project designing before the schedule, especially for the jobs at the beginning;
- having the units ready in the worksite for usage beforehand, which are necessary for operation;
- obtaining necessary construction permits and making construction site deliveries before the delivery of projects which are necessary to start the job earlier;
- providing pre-financing before advance payment;
- having the necessary personnel ready for the start-up in a short time at the worksite;
- using a subcontractor at the start of the job if necessary.

Usually, finishing the job earlier results in additional costs. The additional cost should be less than the cost reduction in total due to finishing the job earlier. Finishing the job earlier as the result of scheduling to an earlier date with the decision of management is out of the scope of value engineering. In case of such a demand, the contractor will have right to claim.

4.3 Quality Improvement and Correction

Quality and value are related with each other one-to-one. Job is not being in compliance in terms of own quality of production and measurement tolerances as defined by the specifications results in these, in general terms:

(1) In terms of production quality:

- determination of project drawing/production and repair method for reconstruction or repair of defects that occur in productions within guarantee period;
- realization of product repair/reconstruction;
- giving guarantee period for performed repair process/reconstruction.

(2) In terms of measurement tolerances:

- reconstruction of products with the abovementioned methods;
- reconstruction of products that are damaged because of reconstruction process;
- In case the mistakes are out of tolerance values

but very close to such values, product can be accepted by the employer. But there may be deductions for last payments in return for excellence in addition to acceptance approval in the quality control minutes. The amounts deducted in return for excellence can be huge.

As it can be understood from the results, additional costs with significant amounts can be in question. Moreover, company will experience a loss of prestige. The most economical production is the production carried out at the quality level demanded on the specifications.

4.4 Reducing Mistakes and Deficiencies in Project Drawings to Minimum

Quality of the projects is one of the factors that affect construction's quality most. The effect of the projects with errors which are not suitable for application on the construction process is negative, while projects without errors or with small errors are suitable for application have positive effect at the same force. It is obligatory to control the drawn projects during the phase of drawing and before the application. One of the methods, applied to reducing project design and drawing errors to minimum or zero is designing three dimensional projects. Therefore, the mistakes, which may occur in the architecture or carrying system, will be prevented from the start.

Thanks to some of the current computer programmes, three dimensional drawings can be prepared and with material and unit definitions, quantity lists can be obtained automatically based on these drawings in order to determine material quantities to be used, with zero mistakes.

One of the methods reducing project preparation time to minimum is simultaneous engineering application. In simultaneous engineering, it is taken as a basis to simultaneously form the projects, which are formed classically with consecutive stages and with the participation of all project partners. So that the mistakes in project drawing can be prevented and time

will be saved by avoiding making returns to previous stages because of project mistakes.

Material and measurement tables in the sheets shall be prepared without any mistake as they are the most important guides for the works of implementers. Reinforced concrete iron lists, tables taken as a basis for topographic works, excavation-filling diagrams steel production sheets and tables can be shown as examples.

Using the most economical sizes and systems for construction elements during project designing, contributes to reach suitable values in terms of costs. With this purpose, optimization methods that minimize construction costs can be used during the design.

5. Changes in Croatia Highway Project to Accelerate the Job and to Reduce the Costs

In this publication, the VE works carried out during the application of Croatia Highway Project, the joint venture between BECHTEL Company from USA and ENKA from Turkey will be explained. The related project was carried out at two different routes:

Section I: Between Bregana - Zagreb (Jankomir) (Fig. 3). In this route the existing old road was

repaired and reconstructed in some areas.

Section II: Because the Section II was not constructed by BECHTEL-ENKA joint venture, details of Section II can not be given. Section III: Here, a new road was made between Basiljevo-Otocac-Sveti Rok (Fig. 4).

Value engineering studies were carried out for various activities in Croatia Highway Project. The information about at what degree some activities accelerated the job and how much cost benefit was obtained is written below. The information on provided time and costs for some activities is not given. Because the related activities are VE studies that are carried out during project preparation stage. Project time and costs provided at the beginning were determined considering the effects of these studies. The activities for which time and cost reduction information is provided are VE studies that are carried out after the project began.

These are the activities that reduce the costs and accelerate the jobs applied on Croatia Highway Project:

The length of climbing forms used on viaduct feet are produced 4 m as standard. The climbing forms were produced as 5 m instead of 4 m by placing special

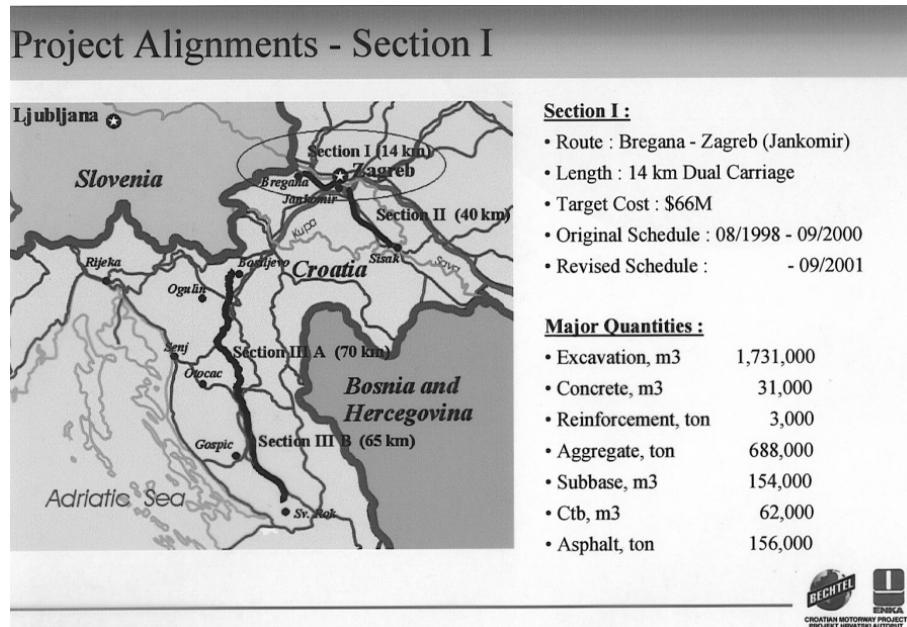


Fig. 3 Croatia highway project: Route 1.

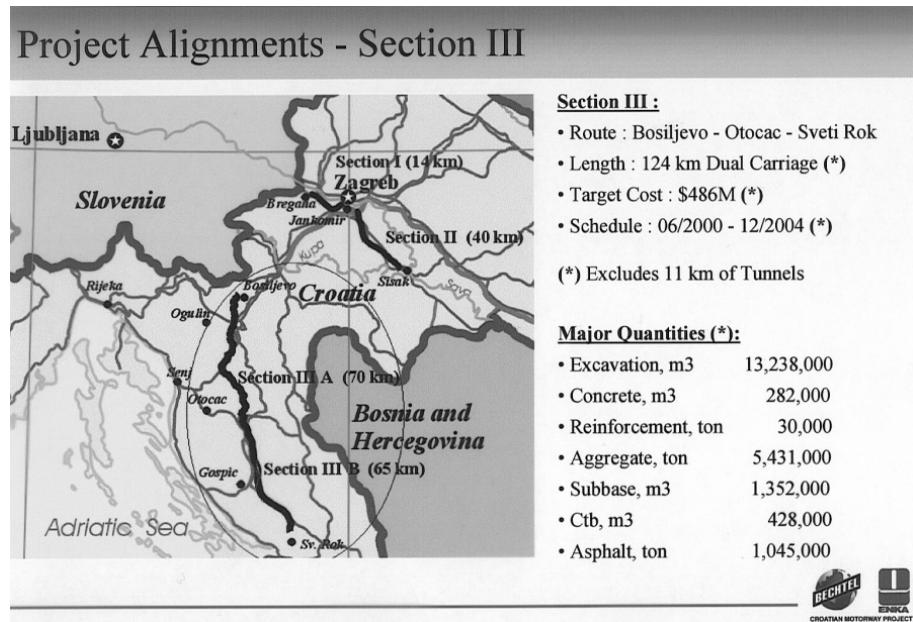


Fig. 4 Croatia highway project: route 2.

order to production company for this project (Fig. 5). As the number of viaducts is high along the way, the special production's cost loss is at a degree that can be ignored. By bringing the length of climbing forms to 5 m, molding workmanship and iron workmanship amount was reduced and job speed increased. Also, iron overlapping number is reduced, which provided savings for the production company. Obtained total cost benefit is \$40,000 and construction time was reduced about one month.

A serious time reduction was provided by making germination with spraying method instead of vegetal earth and germination in splits and fillings.

Time is saved without price change by making supporting wall instead of gabion which requires long production time.

In two bridges with 60 m of opening which require special girder production, \$200,000 cost reduction is obtained by using hammer beam (Fig. 6) and production time was shortened for one month.

In the area where two bridges were built which was critical in terms of job schedule, elevation is reduced for shortening and, therefore, production time was reduced. This situation made it possible to carry out earth works faster, with shorter transportation distance.

The reduction in job amount provided the construction company with \$1,200,000 cost saving and job's time was reduced about two months.

As required by the production method of concrete channels on both sides of the road, it had to be done before asphalt works. In this project, the places where channel was needed to be made were separated by using cold joints, therefore asphalt works were carried out beforehand without waiting for the production of concrete channels and job was accelerated. PEHD (polyethylene high density) pipe system works were carried out instead of concrete pipe system



Fig. 5 Usage of climbing form in construction of viaduct feet [11].



Fig. 6 Hammer beam application on the bridge [11].

for drainage systems with pipe (Fig. 7). Thanks to applied method, a significant reduction was obtained in drainage works which last long and therefore the following works became faster.

Two wild animal passages were built as cast-in-place concrete arch instead of prefabricated building to reduce high cost due to distance of transportation and \$1,540,000 cost-saving was provided (Fig. 8).

The length of Modruš Bridge whose length reached 2,500 m was built as three separate bridges according to change of profile length, and total length was shortened for 850 m. Thanks to this change, the production time was shortened for four months and the construction company obtained \$24,500,000 profit.

The open tunnel whose length reached 440 m was completely cancelled as the result of changing the horizontal and vertical routes, and 75,000 m³ concrete was saved. As the result of this change, \$15,400,000 cost benefit was obtained and the required job time was shortened for four months.

Emergency stop lanes are not used much, therefore, they are exposed to less corrosion, consequently different types of asphalt were used for emergency stop lanes and main road. Asphalts of these two types of lanes are applied separately by leaving cold joint. Emergency stop lanes are not continuous, therefore

requires turning back which results in time losses. In this project, two separate asphalt facilities were used for different asphalt types and production was carried out simultaneously (Fig. 9). Therefore, quality was increased while workmanship was reduced by saving elastic band, cleaning and necessary cutting processes for cold joint production.

6. Results

Competition among the companies in construction sector increases day by day. Companies in competition are addressing their customers with innovations, conveniences, low prices and quality to



Fig. 7 Application of PEHD pipe system in drainage works [11].



Fig. 8 Passage-bridge construction for the passage of wild animals [11].

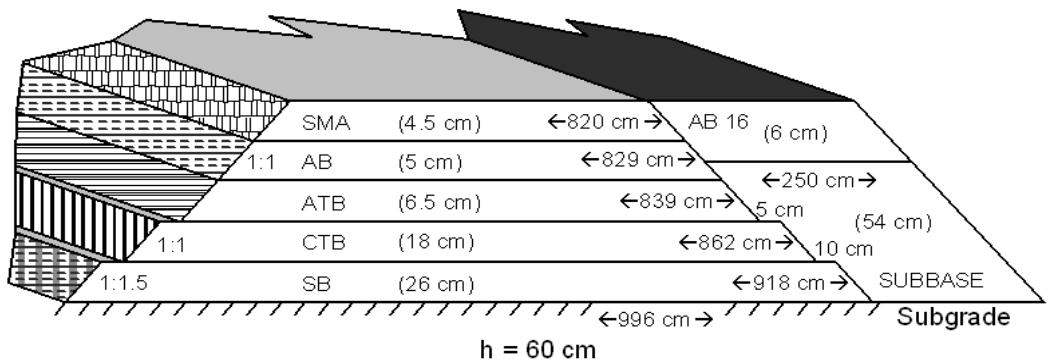


Fig. 9 Highway upper structure section example.

SMA : special mastic asphalt;

AB : asphalt binder / binder;

ATB : asphalt treated base;

CTB : cement treated base.

SB : subbase.

compete with each other. But these mentioned factors are not creating sharp steps for competition, as they are subject to laws, standards and specifications. VE is one of the leading methods for competition by getting free from these elements. VE application directly affects each element in quality-time-cost triangle.

In this project, approximately \$43,000,000 and 12 months of time were saved in total thanks to all these VE works. This saving provided builder company with 6% financial saving and 17% work time reduction.

All of the changes were carried out according to demands of field directorates controlled by project manager, technical examination of engineering director and approval of the management. Subject concerns whole technical management.

7. Conclusions

Success of a project, deciding on where and how a project will be built, completion of the structure according to desired design and building quality, within determined time and cost limits, are all possible with good estimations and solutions. Realism of estimations is completely in direct proportion to success. Carrying out correct estimations is closely based on the knowledge level of the team. Value engineer assumes regulating and analyzing duties to

increase the value of the project while preventing unnecessary costs.

It is not possible to apply VE on each project a company produces. Much more successful value engineering studies can be carried out on complex and big projects which have high potential of restoring the investment. Of course value engineering works have a cost, therefore this project shall be big enough to meet this cost and obtain profit.

The purpose of value engineering is not just reducing the costs, increasing the design standards, making it easier to build the project and saving time and money. VE must create a balance between all the needs of the project.

Purpose of VE shall be determined in direction of company purposes. Every person that joins for VE shall be embraced. There should be no one in the team who thinks in the opposite of project management, or who is suspicious in the benefits of VE.

The highest performance in VE is achieved especially when the purpose is mainly increasing the value rather than reducing the costs.

Production methods developed with VE are carried out to reduce the costs of a product without sacrificing the quality, keeping the cost fixed by increasing the quality or shortening the production time. It shall be never forgotten that VE works are not just the savings

of contractor but also savings that are made in the project in direction of the contractor's and the customer's interests. Contractor's own saving is a kind of economical saving.

When the projects in the world are taken into account for which VE is used; we can see that most of them are applied on civil engineering constructions. Because analyses show that contribution of potential savings from VE applications is much greater at earlier stages of a project. For example, USA Highway Administration added VE into their specifications as an obligation.

When VE applications are regularly carried out in Turkish construction sector, it will be seen that the competition between the companies will increase and prices will become lower. More importantly, systematic working and the quality will increase in addition to them. When contractor quality and customer satisfaction increase, Turkish civil engineering sector will be able to advance much further.

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Intermodality in Italy during the Fascist Period: A Case Study

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Abstract: In the 1930s, when the competition among trucks and trains started, the Fascist government in Italy tried to implement a first form of road-rail integration. As a result, in this period, a transport intermodal network existed for transport services for both freights and passengers. However, the network was quickly lost after the Second World War. The research objective of this paper regards the method of construction of a first form of intermodality (even before this term was used), through the analysis of theoretical texts and achievements of the era. The paper examines laws and regulations issued by the Fascist government. It shows how the willingness to implement a transport policy would lead to having coordinated transport. The success was not only political but also economic, as the coordinated transport may be cheaper and more effective.

Key words: Passenger and freight intermodality, trains and trucks, the 1930s, Fascist period.

1. Introduction

“The railway in comparison to the other means of transport introduces conditions that have allowed to establish a principle of great importance: that of the obligation of the transport. This principle affirmed only in comparison of the railway has an inestimable social value. The commerce and the industry can count on the railway transport, make sure that it will never miss and they can make assignment on the stability of the price that cannot be varied without prescribed formality to ensure the interests of the customers. The obligation of the transport is the correspondent one of the recognition of the monopoly from the State¹. The railway mechanism has had a discipline that has made it become essential element of the national structure, anything of connected to the modern life, of necessary to the social demands. There is no economic difficulty for which you do not ask for help to rail. Human solidarity in the railway has the

best benefit”².

Since ancient times, for the purpose of trade, there were means organized as intermodal transport. It has always been the transfer of goods from cars to ships, from the camels to the barges, from a wagon to another, from a ship to a boat. Nevertheless, the intermodality has brought a great development in the last two centuries, for the arrival of the train and the motor transport. Trains and trucks have increased the traffic of commodities within the States. They have created competition, before between railways and rivers or channels, then between trains and trucks.

This essay is dedicated to the first attempts to coordinate the various means of transport and to carry containers transferable from one means of transport to another. The study refers to the first half of the 20th century, particularly the 1930s, when the debate on intermodality had not yet

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¹In Italy, the railway were nationalized in 1905, creating the State Railway (Ferrovie dello Stato).

²F. Tajani, Competition and monopoly in transport, The fight between rail and car (Concorrenza e monopolio nell'esercizio dei trasporti. La lotta tra ferrovia ed automobile), Milan, 1936, p. 46.

developed³.

In the 19th century, the State started to practice more functions in the sector of the transports, assigning to private societies the construction and the management infrastructures, or constituting public firms as the State Railways founded in 1905 or their correspondent at a local level, the firms of transport of the Communes, provided from a law of 1903⁴.

At the beginning of the 20th century, it was thought the creation of networks of multiple carriers in an overview. For example, in 1907, it was imposed by law the so-called “cumulative service” among vectors of transport, to favor the development of traffic. The enterprises of transport were invited to join among them and to conclude a single contract of carriage, to favor the consumers, that paid only once for a consignment on more vectors with the same or with different ways of transport⁵.

In the 20th century, it has become increasingly clear the need for a transport policy which can coordinate transport and not only to promote the traditional development of mobility. The development of mobility had always been the purpose of the transport policies: for instance, the Roman roads or the intervention of States in the naval sector.

To coordinate the ways of transport means to stimulate the use of the most proper mean for the demands, since any mean could guarantee the best technical-economic conditions for all transports. This

³Le transport combiné: 50 ans d'expérience, sous la direction de Michel Rachline, Compagnie nouvelle de conteneurs-transports nationaux et internationaux, Ed. Atlas, 1997; COST 340, towards a European intermodal transport network: lessons from history: a critical bibliography, edited by Michèle Merger and Marie-Noëlle Polino, Paris, AHICF, 2004.

⁴Law 29 marzo 1903 n. 103, “Direct taking of public services by local authorities”, according to which the municipalities could take the direct exercise, among other services, tramways animal traction or mechanical.

⁵Law 7 luglio 1907 n. 429, “Structure of the exercise of State Railways not granted to private companies”. Article 42 recited: “It is mandatory for rail connected to each other, the establishment of cumulative service.... The obligation of cumulative service or mail, as appropriate, will be enrolled in any granting new or renewed for land transport companies, and shipping companies subsidized by the state or local authorities”.

need was very felt in the years 1920s and 1930s, due to the diversification of means of transport and competition between them. In this period, a debate developed on rates suitable to foster trade, and interventions were needed to restrain competition among trucks and trains.

But it was a new situation and nobody knew what steps to take.

In the 1930s, a lot of studies on the competition between road and railway were produced⁶. In Italy, the Fascist government put into effect measures for rationalization of motor transport, adopting innovative solutions, subsequently abandoned after the Second World War.

2. Debates and Proposals in the 1930s

Until the roads were frequented only by animal-drawn vehicles, the railway offered a faster service and more convenient prices. The animal traction was a completion of the railway transport. The consignments were transported with wheelbarrows to horses from the store of the sender to the station of departure and then from the station of arrival to the warehouse of the consignee.

The truck changed the situation, because, thanks to motorized transport, it was possible to go “from door

⁶Compare, such as: P. Biraghi, Defense of the railway and tramway traffic (Difesa del traffico ferro-tranviario), Rome, 1931; Q. Capaccioli, Discussion on competition between rail and car (Discussioni sulla concorrenza fra ferrovia e automobile), Florence, 1933; F. Corini, Economic comparison between the various means of transport (Confronto economico fra i vari mezzi di trasporto), Parma, 1934; B. Bolis, Roads for trucks and railways (Strade camionabili e ferrovie), Rome, 1936; V. Mezzatesta, Transport in the economic life of the Nation and the issue of motor vehicles (I trasporti nella vita economica della Nazione e la questione automobilistica), Rome, 1935; A. Pavone, Motor vehicle and rail (Autoveicolo e ferrovia), Rome, 1935; F. Tajani, Competition and monopoly in transport. The fight between rail and car (Concorrenza e monopolio nell'esercizio dei trasporti. La lotta tra ferrovia e automobile), Milan, 1936; R. Trevisani, (The competition between road and rail transport in economic policy) La concorrenza fra la strada e la rotaia nella politica economica dei trasporti, Milan, 1937; F. Vezzani, Land transport (I trasporti terrestri), Florence, 1937; A. Pagello, On a form of coordination of transport (Su una forma di coordinamento dei trasporti), Vicenza, 1939.

to door", making to save the expense of load and unloading of the railway wagons and the two animal-drawn transports. The truck could compete with the train even if it asked for more elevated prices for the transport of the commodity. The advantage of the truck went down with the growth of the total run. Competition of mechanical traction on the road was more effective on short distances and less effective over long distances.

Besides, the truck allowed to eliminate or to reduce the expense of packing. The trucks were escorted for the whole trip by the same person, the driver, who could assume the responsibility of the load without a minute packing of the commodity, while the railway was very demanding and bureaucratic.

The transport on trucks did not have excessive formalities and allowed to bargain the price of transport from time to time. Instead, in the railway, there were invariable prices, of difficulty calculation, accompanied by complicated and binding conditions. The railways, accustomed to a monopoly, had exaggerated the bureaucracy of their duties⁷.

This awareness spread to the early 1930s. To face the trucks, the railways lowered the rates in all cases in which the competition entered, maintaining the previous rates where the competition did not exist. One of the hinges of the public service, the parity of treatment, ended. Besides, the elevated prices were paid by the poorest clientele, that of the countries with little traffic, where motoring did not exist. The damage of the competition was twofold: to move a portion of the costs of transport from users to taxpayers and the destruction of equal treatment borne by the population less favored.

Among the measures to resolve this situation, it was proposed to adopt a partnership between rail and road transport, which was an agreement to divide the field of freight transport. But the accord between the railway and a big number of enterprises of trucks was not possible. Moreover, the lorries were in

⁷F. Tajani, Competition and monopoly in transport, pp. 28-29.

competition with each other, as well as being in competition with the railway⁸.

In Italy, there was a long discussion on the proposal to apply to freight service to the institution of concession applied to the bus in the early years of the 20th century. The concession was a government licence, which included an agreement between the State and the private company, that provided precise requirements for transport, in exchange for a monopoly over a certain route or for a certain service.

The system of government license for the bus lines had not created problems and had helped to develop the traffic in the regions devoid of railways and tramways, eliminating the problems that were encountered in other countries due to the excessive competition of bus lines, both between them, and with the railways and tramways⁹.

Among passenger services and commodity services, there was nevertheless a substantial difference. The traveller services had the obligation of the regularity of the schedule, while for the commodities this obligation did not exist.

In fact, the transport of foodstuff and pressing consignments were provided the same bus called "postal coaches". The other transports of commodities, did not have usually a character of such urgency to impose the departure of a truck to a fixed date and with fixed itineraries, but with an incomplete load. For this kind of transport, the criterion of greater economy always prevailed over that of regularity.

Besides, for the commodity services a determined itinerary could not be established, since the truck had to go to load the commodity to the station or to the store of departure, and to unload it to that of destination with varying itineraries of time in time. Therefore, in Italy, it was thought that it was not appropriate to establish the concession for freight

⁸F. Tajani, Competition and monopoly in transport, p. 39.

⁹Law 12 luglio 1908 n. 444, "construction and concession of railways, trams and suburban bus lines and lake navigation in public service".

services¹⁰.

A measure put in place consisted in the institution of intermediary corporate bodies which had the function to assume the transports for a global price which included the rail and road fee. It dealt with creating a corporate body able to be on the market together with the private firms of transport, which was not submitted to the rigors and the ties of the public administrations¹¹.

The existence of the intermediary institute did not eliminate, however, the cause of the competition and the intermodal transport was preferred only if the total cost resulted smaller.

The establishment of an intermediary institution and the imposition of a tax, in order to balance the costs between trains and trucks, were founded attempts to cope with competition road/rail during the 1930s.

3. Italy Looked Like Other European Countries

The growth of the traffic commodities on the trucks found unprepared the political authorities, that left full liberty to the transports with truck in the first times, without worrying about the consequences. Then, the governments were induced to run for cover because of the gravity of the damages suffered by the railways. The situation in the mid-1930s was as follows.

In England, with a 1930 law the concession had been introduced for the public services of the travellers, but up to 1934 the trucks enjoyed of full liberty. In January 1934, it went into effect a new rule, which extended to freight services the obligation to grant, when trucks made services out of the circle of the city. There were three types of licenses: the first Type A to be issued to those who transported goods of others (the professional road hauliers), the second Type B for those carrying goods of themselves or others; and the third Type C for those carrying only their products.

¹⁰F. Tajani, Competition and monopoly in transport, pp. 53-54.

¹¹But what is this INT? (Ma che cosa è questo INT?), extract from Bollettino di Informazioni 5 (October-November 1956), p. 1.

The third type of license was granted on simple request, but sometimes merely granting the transport of specific goods and certain routes or traffic areas.

In France with a decree of April 1934, the concession was introduced for the public services both of travellers and commodities. If the railway companies were opposed intervened an arbitration entrusting a commission where the railways, drivers and users were represented. If the arbitration response were contrary, the Ministry of Public Works denied the concession. Some small railway stations were closed, but it was recognized that the maximum in long-distance transport was entitled to the railways.

In Switzerland, without adopting laws that regulated the auto transport of the commodities, the problem was solved by creating an intermediary institute that would have had to realize the collaboration. A proposal of law that had the tendency to regulate the transports of commodities with trucks, to the purpose to limit the competition to the railways, it was rejected from the popular referendum.

In Germany, the concession did not exist for the services travellers, while for the commodities it was made distinction among the traffic to small and that to great distance. In traffic, at a small distance ranged transport not more than 50 km. For these transports, like those made by individuals on their own, permission from the authorities was not necessary.

Instead, the transports for more than 50 km done for other people's account were subdued to a concession, with the prohibition to adopt costs too low to avoid damage to the railway. In addition, carriers had to gather in a consortium that had to enter into a contract with Reichsbahn for the division of the areas.

In Austria, the concession of the services commodities was founded in 1933, as it already existed for the services travellers.

In the different national legislations, some common characters were found:

(1) Distinction was made between transport operations on their own and with their own means and

transported on behalf of others. Transport on own account were always most favorite;

(2) Distinction was made between short-distance transport and long-distance transport. The first thought to be suitable to the truck, the second to the rail. Transport within short distance was left larger freedom, those long distance were allowed with some restrictions or even prohibited;

(3) There was a tendency to the monopoly for the Railways, making to intervene the railway administration in the inquiry for the concessions or in accords to divide the traffic;

(4) It was common to all the legislations that the tendency to put taxes on the auto services, to safeguard the railway traffic¹².

This last provision was adopted in Italy in 1935. Since the rates of the trucks were too low in relation to the rail, a decree law of December 1935 taxed for 1.2 cents every quintal-km transported on truck for third parties and for 0.8 cents every quintal-km transported in own account, with exclusion of the connections among stations and place not served by the trains¹³. Transport carried out within the boundaries of the province, that were used to carry out the normal activities of a farm, were also exempt from duty. With such decree the firms of transport were also forced to hold registers of load and unloading of goods in order to be checked and to have a minimum of order in the administration.

The most important intervention was the constitution of the INT (National Institute of Transport), formed in 1929 when it was begun to warn the competition especially in the Valley Padana, that is in the richest part of the Country.

4. The National Institute of Transport

Following the examples of Switzerland and France, where some intermediary bodies had been founded to handle freight traffic. In 1929, the Italian State

¹²F. Tajani, Competition and monopoly in transport, pp. 49-50.

¹³Royal Decree-Law 2 December 1935 n. 2.097, "tax on transport of things with vehicles".

Railways (FS) were authorized to participate in enterprises in form of stock companies, having as purpose the acquisition and the increase of the transports for railway and the exercise of complementary services¹⁴.

The INT was created for this purpose. The undersigned initial capital was of 28 million liras, of which 21 million liras are from the State Railways, that did not put money. The State Railways conferred services as the shipping agencies of cities, the rights of use of the stores and the railway areas, the transmission of correspondence and telegraphic and telephone dispatches¹⁵. The remainder of the social capital, that is 7 million liras, was versed from the banks of investment: Commercial Bank, Italian Credit, National Bank of credit and Bank of Rome, that went out in 1936 for the new banking law that imposed the separation between bank and industry. To that point, the FS ransomed the 7 million and they remained the alone stock of the INT.

The action of the INT practiced especially in services in small quantities, that is, on the trafficking of various goods which did not fit the railway, which was a wholesaler rather than a retailer of transport. For the State Railways, the unit was neither the ton-km nor the wagon-km, but the train-km¹⁶.

To the INT which was assigned the acquisition of transport in small quantities, the task of the so-called "groupage" was to group them in order to make shipments to full wagon (wagon groupage). The INT was therefore devoted to this specific activity, both through its "delegations" (branch offices), both in partnership with the shipping agencies.

According to the convention July 14, 1929 with the State Railways, to the National Institute of Transport was granted the delivery of goods at home by its own

¹⁴Royal Decree 13 maggio 1929 n. 836, "participation of the State Railways in companies with a view to the acquisition and increase of rail transport and the operation of complementary services".

¹⁵Istituto nazionale trasporti, In twenty-five of the INT (Nel venticinquennale dell'INT), Rome, 1955, p. 15.

¹⁶But what is that INT?, p. 1.

trucks. The INT began such activity on January 1, 1930 and before June 30, 1930, it also assumed the exercise of 118 agencies of shipping¹⁷.

The agencies of new institution and some of those existing extended the service of transport for distant places from the stations. Communes were connected distant from the railway up to 40 km and it was made possible, also for small centers, a regular service that offered the safety of accessible and equal prices in any period of the year¹⁸.

The concept was to concentrate by truck, a good quantity of goods in a big station, put it on a fast railway service to another station and then to drain the whole by suitable trucks to the individual recipients. It was in fact the response of the railways who came in the truck to stand up to competition of this, using it as a means connected to the train.

At the beginning, the INT had the role to call the great societies, offering them special tariff facilitations, in order to make the railway transport more advantageous, completing it by a truck service that would allow the forwarding of the goods to the customer location.

In 1931, the INT had already repurchased to the State Railways around 200,000 t of commodity. Other 247,000 t of goods were taken from the train and carried to the recipients, coordinating trains and trucks¹⁹.

From July 1931 to June 1932, the INT opened 46 new shipping agencies of city, extending besides the home service to around 300 new places not served by the railways. In some places, the agencies of city realized the collection and delivery of express packages and luggage at home.



Fig. 1 Truck of the INT.

Source: G. Gazzetti, *Il treno in casa*, Quaderni delle Ferrovie Italiane dello Stato, n. 8, edizione 1957, p. 76.

In June 1932, the shipping agencies of city were 337, which grew to 360 in June 1934, including the direct management of the largest agency of the city of Milan. In June 1939, the agencies of city were 373 with 415 addresses in suburban locations. Besides, the INT directly managed the Agencies in Milan and Trieste, from January 1939, also in Rome.

After the Second World War, the service of the delegations INT had a further expansion reaching 449 to June 1956, of which 14 were conducted in direct management by the institute²⁰.

Besides, to the INT, some passenger services by bus were entrusted replacing the train services²¹. The buses of the INT replaced the trains in two secondary lines Giulianova-Teramo and San Benedetto of the Tronto-Ascoli Piceno, since March-April 1932. The substitution happened in base to the regal decree-law December 21, 1931 No. 1575, that authorized the State Railways to replace the railway services by coach services for passengers and for commodities.

Other passenger services were subsequently assigned to the Institute: In June 1938, the coach

¹⁷ Ministero delle Comunicazioni: Amministrazione delle Ferrovie dello Stato, Report for the financial year 1929-30 (Relazione per l'anno finanziario 1929-30), Rome, 1930, p. 141.

¹⁸ Ministero delle Comunicazioni: Amministrazione delle Ferrovie dello Stato, Report for the financial year 1930-31 (Relazione per l'anno finanziario 1930-31), Rome, 1931, p. 146.

¹⁹ G. Gazzetti, *The train at home*, pp. 71-72.

²⁰ Ministero dei Trasporti. Ferrovie dello Stato, Report for the financial year 1955-56 (Relazione per l'anno finanziario 1955-56), Rome, 1957, p. 224.

²¹ Ministero delle Comunicazioni. Amministrazione delle Ferrovie dello Stato, Report for the financial year 1955-56 (Relazione per l'anno finanziario 1955-56), Rome, 1932, pp. 122-126.

services managed in substitution of railways measured 388 km and those gotten in concession 787 km²².

To create a network of public road transport at the national level, the State could use the INT. Instead, after the Second World War, it was decided to make room for private companies and a great number of bus companies were established at the local level.

In conclusion, the complex of concessional coaches of the INT was not so important, compared to the national network of coaches, to become effective instrument of State policy to guide the development of the road transport of travelers²³.

5. The Italian Transports Company East Africa

In East Africa, after the conquest of Ethiopia from Italy, in August 1937, a company for the coordination of all trucking services was founded, named CITAO (Italian Transport Company East Africa). The company did not have ends of profit and could acquit its own duties being free from the bureaucratic procedures of the State. The company watched over on the organization of the enterprises and on the efficiency of their vehicles. Besides, it distributed the loads among the authorized firms, holding back on the hires a share of 4%. The advantage for the firms of truck was to be able to receive the price of the transport within 10 days from the offices of the company. The CITAO got a great success. Its functions had widened in 1939, when any activity inherent to the transport was entrusted to the company. The CITAO also practiced the autolinees on the main routes and also began after 1939 to manage the urban buses, that were activated in the principal cities of the colonies up to the Italian defeat in the Second World

War²⁴.

6. Railway Links and Containers

With regard to the technical means by which it was attempted to facilitate intermodal transport in order to give work to both trains and trucks, we can mention the railway links, very useful for factories and department stores.

Before the motor transport assumed importance, the State Railways did not promote the construction of the links: indeed, they hindered in any way with technical pretexts and they made a very expensive exercise, applying high taxes.

When they changed policy for the arrival of the competition, the demand for railway links decreased, as a consequence of the perfecting of trucks.

Some big bogies were also created, equipped with wheels to tires, which could go from the railway tracks to city streets, carrying the railway wagon with the help of a powerful tractor, so that it reached the recipient's home address. Such means of conveyance met, however, limitations on the narrow roads of the cities. It was also a very expensive transport that could not have spread²⁵.

Other technical means, which emerged with the arrival of competition, was the transport container with boxes large enough to accommodate both the truck and the railway wagon.

The State Railways participated in the work of the competition organized by the International Chamber of Commerce, along with other bodies, on the initiative taken by the World Congress of the car in 1928 for suitable types of containers²⁶.

Besides, the State Railways decided to participate in a society for the construction and the exercise of the containers.

²² Ministero delle Comunicazioni. Amministrazione delle ferrovie dello Stato, Report for the financial year 1955-56, p. 106.

²³ Istituto nazionale trasporti, In twenty-five of the INT, pp. 18-19.

²⁴ S. Maggi, Colonialism and communications: The railways in Italian Africa (Colonialismo e comunicazioni. Le strade ferrate nell'Africa Italiana), Esi, Naples, 1996, pp. 232-233.

²⁵ F. Tajani, Competition and monopoly in transport, pp. 40-41.

²⁶ Ministero delle Comunicazioni: Amministrazione delle Ferrovie dello Stato, Report for the financial year 1930-31, p. 127.



Fig. 2 Container refrigerants for carriage of perishable foodstuffs.

Source : G. Gazzetti, *Il treno in casa*, Quaderni delle Ferrovie Italiane dello Stato, n. 8, edizione 1957, p. 73.

The Sicon (Italian Society for Containers) was set well soon in liquidation, but the State Railways continued the construction of a certain number of mobile boxes and equip materials for the activation of a regular service on certain lines of traffic. The railway administration also participated in the works of the Bureau International des Containers for the resolution of technical problems, tariff and customs relating to international cargo of goods in the containers. In Italy, the dispositions for the transport of commodities with containers were established with ministerial decree published on the Official Gazette of January 25, 1933²⁷.

Two separate types of containers were set: a heavy type with a maximum weight of 5 t and a light with a maximum weight of 2.5 t.

For the service of taking and delivery²⁸, 322 containers of various types were used for experiment in 1936-1937, entrusted the management of the National Institute of Transport. Such boxes in 1938-1939 had become 2.522²⁹.

However, there was not a strong tendency to make use of the container. It was noticed, a greater demand

for road trailers built to transport freight wagons, facilitating transport services from door to door.

During the Second World War, the conditions changed and transport had to adapt to the necessities of war, recovering also the traditional modality that used the rivers and had been abandoned.

The report on the management of the 1941 State Railways has been affirmed.

Always to the purpose to reserve the greatest possible quantity of rolling stock to the war necessities, the attention of the administration has been directed in order to make flow into the waterways, in the Veneto region and neighboring areas of bulk goods normally transported by rail. To such necessity a service of transports has been founded from Veneto to the Lombardy by mixed river and truck. Transport by boat were limited to Ostiglia, where the goods are transferred to trucks for forwarding to the places of destination³⁰.

7. Conclusions

The attempt to coordinate transport in an overview, pursued by the Fascist regime, obtained a good success during the 1930s, when laws and institutions were created for this purpose.

Despite the propaganda autarky pursued in this period, Italy was included in the themes of the other European countries which looked at as role models to follow and imitate in the transport sector. There were, therefore, some achievements in other European countries, from which stemmed the national choices.

In 1935, the road freight traffic was regulated, providing that companies should be authorized by the Ministry of Communications through the General Inspectorate of the railways, trams and cars, on the basis of the eligibility requirements.

The road freight traffic was taxed to avoid trucking rates were too low compared to those of the trains,

²⁷G. Gazzetti, *The train at home*, pp. 38-39.

²⁸Ministero delle Comunicazioni. Amministrazione delle Ferrovie dello Stato, Report for the financial year 1936-37 (Relazione per l'anno finanziario 1936-37), Rome, 1938, p. 94.

²⁹Ministero delle Comunicazioni. Amministrazione delle Ferrovie dello Stato, Report for the financial year 1938-39 (Relazione per l'anno finanziario 1938-39), Rome, 1940, p. 107.

³⁰Ministero delle Comunicazioni: Amministrazione delle Ferrovie dello Stato, Report for the financial year 1940-1941 (Relazione per l'anno finanziario 1940-1941), Rome, 1941, p. 182.

with the exception of connections between stations and places not served by trains.

Since 1929, the INT, a subsidiary of Ferrovie dello Stato, tried to overcome one of the advantages that the car had compared to rail: the service from door to door.

The desire to promote intermodal transport, both in goods and in the passenger sector, was abandoned after the Second World War, when attempts to coordinate transportation nationwide were overcome by the enormous spread of road transport. The debate on intermodality was resumed with the European Common Market in 1957, but it was international intermodality, no longer at the national level.

In the post-war Italy, the huge growth of trucks and cars led politicians to choose road transport as the future of mobility, making a strategic mistake that still Italy pays with pollution and traffic congestion.

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Addressing the Fuel Resistance of Hot Mix Asphalt by an Enhanced Test Method

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Abstract: In areas where HMA (hot mix asphalt) is likely to be exposed by any form of mineral oil, the layer has to withstand the attack of these substances in order not to damage the construction. The European standard EN 12697-43 provides a test procedure to determine the resistance of HMA to fuel. The paper reviews this method thoroughly. A completely revised and simplified test device for the brush test was developed meeting the requirements of the standard and creating results with a high repeatability at the same time. The test conditions given by the standard such as the exposure to fuel, cleaning of the specimen after exposure or the contact pressure of the brush were varied to isolate those test conditions with a substantial influence on the result. The research revealed that in the standard some conditions with a rather small influence are set quite strictly while other conditions with a distinct influence on the result are not defined with the required accuracy to obtain comparable and repeatable results. The paper presents suggestions for the improvement of the test method and the standard itself in respect to the layout of the test device and the definition of important test conditions to enhance the outcome of the EN 12697-43.

Key words: Fuel resistance, hot mix asphalt, abrasion test.

1. Introduction

HMA (hot mix asphalt) is mainly used in road construction for flexible pavements but is also suited for traffic areas on airports, parking lots, or at gas stations. When these layers are subjected to any form of mineral oil, such as kerosene, diesel or benzine (gasoline), the HMA has to resist fuel exposure in order not to damage the construction.

For the assessment of the resistance to fuel, different test methods have been developed in the last 20 years [1-3]. The tests can be divided into two main groups or a combination of both. Chemical methods include tests where asphalt or bitumen specimens are directly exposed to fuel without any mechanical loading. The effect of the fuel exposure is quantified by different means, e.g. the penetration depth of the liquid, the mass loss of asphalt specimens or the chemical change of the bitumen itself.

In many cases, these chemical methods are

combined with subsequent mechanical testing. These tests include the determination of strength or stiffness parameters and the mass loss due to abrasive loading. In some cases, reference specimens not exposed to fuel are also tested to isolate the influence of the fuel. From the wide variety of test methods developed in the last decades, the European standard EN 12697-43 (2005) "resistance to fuel" chose a direct exposure of asphalt specimens to fuel followed by a brush test to obtain mass loss due to chemical and abrasive loading. The brush test is often used in research to determine resistance of HMA to fuel [4]. It can be seen as a modification of the wet track abrasion test [5].

In an extensive research program, the contents of EN 12697-43 (2005) were critically reviewed and test conditions systematically varied to isolate those conditions with a distinct influence on the test results. The findings of the project can account for an efficient improvement of the standard.

2. Resistance to Fuel acc. to EN 12697-43

According to EN 12697-43 (2005), a cylindrical

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specimen with a known mass is immersed partly in a bath with the specified fuel. For bituminous mixtures with paving grade bitumen, the specimens are exposed for 24 hours, whereas for specimens with polymer modified bitumen the exposure should last for 72 hours. The standard states that the immersion time for mixes with paving grade bitumen and polymer modified bitumen should be 24 h if the performance of mixes with both bitumen types is compared. For each material, at least three specimens are to be tested. In case of porous asphalt, the specimens shall have a diameter of (150 ± 2) mm, for other asphalt mixes the diameter is set to (100 ± 2) mm. According to EN 12697-43 (2005), the height can range between 40 mm and 60 mm.

Before testing the dry mass of the specimen is recorded as m_1 . After the exposure, specimens are cleaned with water and dried for another 24 hours at 25 °C. After drying the mass of the specimen is measured as m_2 and the immersed surface is inspected by visual means. The immersed surface is then subjected to abrasion by a steel brush, which is moving in epicycloid passages over the surface. After 30 s (m_3), 60 s (m_4) and 120 s (m_5), the remaining mass of the specimen is recorded. The material loss after the immersion and the brush test are used as parameters to quantify the resistance to the particular fuel. Therefore, two parameters are introduced in EN 12697-43 (2005):

$$A = \frac{m_1 - m_2}{m_1} \cdot 100 \text{ [%]} \quad (1)$$

$$B = \frac{m_2 - m_5}{m_2} \cdot 100 \text{ [%]} \quad (2)$$

where, parameter A determines the mass loss due to exposure to fuel (chemical loading), whereas parameter B quantifies the mass loss due to abrasive loading. The resistance is characterized by a combination of the two parameters in EN 12697-43 (2005):

- $A \leq 5\%$ and $B < 1\%$: good resistance;
- $A \leq 5\%$ and $1\% \leq B \leq 5\%$: moderate resistance;
- $A > 5\%$ or $B > 5\%$: poor resistance.

3. Materials and Test Program

Within the research program, two different mix types were tested. One was an AC 11 PmB 45/80-65 asphalt concrete with a maximum aggregate size of 11 mm and a polymer modified binder PmB 45/80-65 acc. to ONORM B 3613. The other mix was an AC 11 PmB 45/80 FR (fuel resistance). The basic bitumen is a PmB 45/80-65 plus additives to increase the FR. The binder content was varied from 5.0% to 5.6% (m/m). The target volume of air voids ranged from 3.0% to 7.0% (v/v). An overview is given by Table 1.

Table 2 shows the variation of test parameter within the project. Specimens were prepared from Marshall compaction (EN 12697-30) as well as from slabs compacted by roller compaction (EN 12697-33). Three different methods of specimen cleaning after exposure (W1 to W3) were investigated (see Section 4.3). Furthermore, the static loading for the abrasion test was varied and three different types of fuel were analyzed.

Table 1 Materials used within the research.

Mix type	Binder content (% (m/m))	Volume of air voids (% (v/v))
AC 11 PmB 45/80-65	5.0	3.0
	5.3	5.0
AC 11 PmB 45/80 FR	5.6	7.0

Table 2 Test parameters.

Specimen preparation	Method of specimen cleaning	Duration of exposure (h)	static loading (N)	Fuel type
Marshall compaction	W1	24	140	Kerosene
	W2			Diesel
Roller compaction	W3	72	210	Benzine

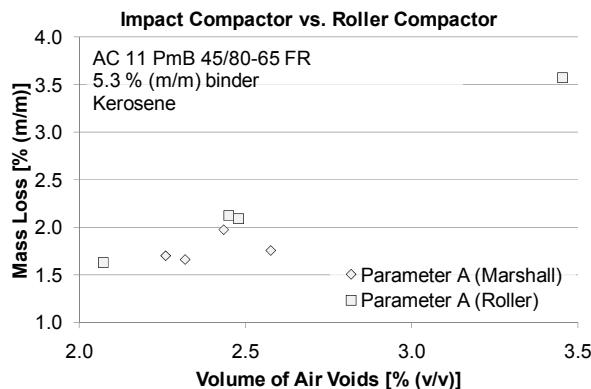
4. Review of EN 12697-43

Reviewing the test procedure given by the standard, this section provides detailed suggestions for improvements:

- Preparation of specimens;
- Dimensions of specimens in relation to fuel exposure;
- Cleaning of the specimens after exposure;
- Determination of fuel resistance acc. to new parameter C ;
- The testing device for the brush test.

4.1 Preparation of Specimens

Acc. to EN 12697-43, the mix can be compacted by impact (Marshall) or gyratory compactor (EN 12697-30 and 12697-31). Also cored specimens from road pavements can be used. Roller compaction (EN 12697-33) is not a given option by the standard. A comparison within the research project showed that the difference in results between Marshall specimens and specimens cored from HMA-slabs compacted by roller compaction is not significant. As an example the left diagram in Fig. 1 shows the mass loss after exposure (parameter A) of four specimens for each preparation method vs. the volume of air voids. Thus, it is suggested that all three compaction methods are implemented in EN 12697-43, especially because the roller compactor reproduces the compaction used in road construction in the most reliable way [6].



4.2 Dimensions of Specimens in Relation with Fuel Exposure

EN 12697-43 demands to place each specimen in a beaker glass in an amount of fuel so that the specimen is immersed 35 mm in the fuel. As the height of the specimen can range between 40 mm and 60 mm but the immersion of the specimen is fixed to 35 mm of fuel, the ratio of specimen volume vs. immersed volume ranges from 58% to 88%. This means that smaller specimens are exposed to a much higher extent to fuel leading to higher mass losses. Thus, results from specimens with different heights cannot be compared.

The recommendation is to set the height of the specimen in the standard more strictly (e.g., 63.5 ± 2 mm) or set the immersed part of the specimens relative to the specimen's height (e.g., $50\% \pm 1\%$).

4.3 Cleaning of Specimens after Exposure

After exposure, the specimens have to be cleaned from the fuel. The standard demands to “wash the specimen with water until the acidity of water pH is (7.0 ± 0.5) ”. This wording is imprecise. After exposure, part of the binder has been dissolved by the fuel, so the surface of the immersed part of the specimen shows more or less loose stones. Depending on the method of washing, more or less of these stones are washed away leading to different results for parameter A for the same material. To demonstrate

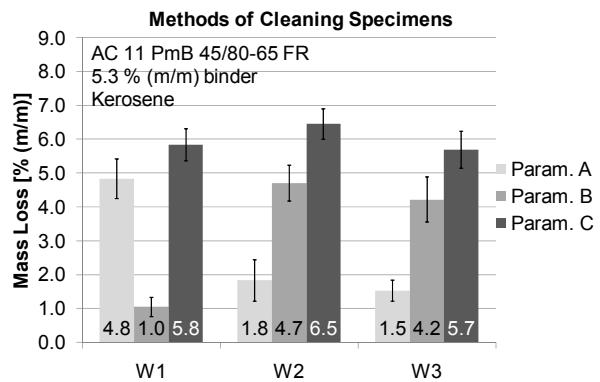


Fig. 1 Results of specimens from impactor and roller compactor (left); impact of cleaning method on results (right).

this, within the research project three different methods of washing were investigated. One method was to clean the specimens under flowing water and removing loose aggregates “mechanically” by hand (W1, Fig. 2a). Another way of washing included cleaning the specimen under flowing water but removing loose aggregates only carefully with a hair pencil (W2, Fig. 2b). The third way was to clean the specimen just by putting it into a small box with water not directly under jet of water until the required acidity of water was reached without any “mechanical” removing of loose aggregates (W3, Fig. 2c).

The impact of the method of cleaning—especially removing of loose particles—on the results is crucial. Results for the three different methods are shown in the right diagram in Fig. 2. For each method, four specimens were tested. As the volume of air voids of all specimens is similar (MV : 2.5% (v/v), SD : 0.2% (v/v)), the diagram shows the MV (mean values) and SD (standard deviations) for each method and the parameters A and B .

It is obvious that the most aggressive way of cleaning (W1) leads to the highest mass loss after exposure (parameter A). Methods W2 and W3 lead to the similar results. Regarding the mass loss after brush testing, the situation is reversed. The specimens cleaned aggressively now show low losses, whereas specimens cleaned according to W2 and W3 lead to higher mass losses (parameter B). If the parameters A and B are combined to an effective mass loss after exposure and brush test (indicated as parameter C in the right diagram in Fig.1), comparable results are

received independent of the method of washing. The scattering of the results in terms of SD is not dependent on the method of washing.

It is strongly recommended that the method of cleaning after exposure is precisely given by the standard in the future. As the parameter A should only quantify the mass loss of a material when exposed to a fuel substance without any abrasive loading, the specimens should be cleaned carefully either by washing it under flowing water without removing loose aggregates by hand or by putting it into a box keeping it out of the direct jet of water. The standard should state clearly that the surface of the specimen should not be rubbed while cleaning with water and additional it must be explained how to remove loose particles. Furthermore, we recommend altering the determination of the fuel resistance. Today, EN 12697-43 obtains the fuel resistance by parameters A and B . As shown, different methods of washing lead to a wide range of these parameters for the same material. Thus, the results cannot be seen as comparable or repeatable. It is recommended to implement a new parameter C as presented in the next section.

4.4 Determination of Fuel Resistance acc. to New Parameter C

The influence of the method of cleaning the specimens after exposure on the fuel resistance can be overcome by introducing a parameter C :

$$C = \frac{m_1 - m_5}{m_1} [\%] \quad (3)$$

Parameter C indicates the total loss of mass after

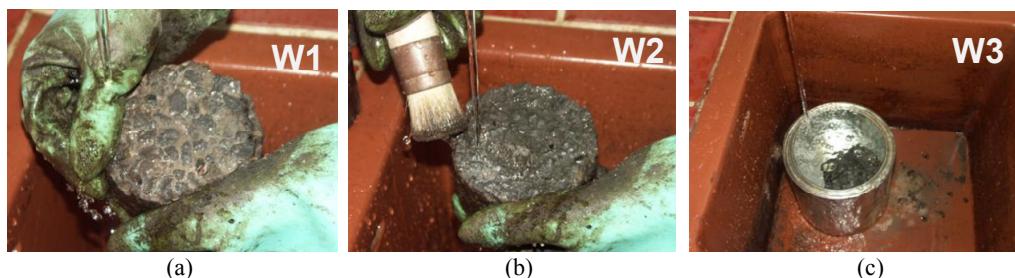


Fig. 2 Three methods of cleaning specimens after exposure.

chemical and abrasive loading. As shown in the above section, this parameter is independent of the method of cleaning. The resistance can be characterized as follows:

$C < 6\%$: good resistance;

$6\% \leq C \leq 10\%$: moderate resistance;

$C > 10\%$: poor resistance.

Parameters A and B will still be obtained as an information how the tested material reacts to fuel exposure and abrasive loading, respectively.

4.5 Testing Device for Brush Test

For the brush test, EN 12697-43 provides an example device including a Hobart mixer which should be able to carry out epicyclical motion covering an area of 100 mm in diameter with a rotation speed of 60 ± 2 rpm. The mixer in this case carries the brush. To fix the specimen under the brush and to realize a constant pressure of the specimen to the brush during the test, a frame is presented in the standard working with compressed air in Fig. 3. On closer examination, this system cannot guarantee that the pressure produced by the compressed air is fully effective for the contact pressure of the specimen to the brush. The skin friction of the steel rings and the wedges used to fix the specimen within the frame will transfer part of the forces produced by the compressor. Furthermore,

the contact pressure cannot be kept constant throughout the test when the height of the specimen is reduced due to abrasion of the brush since the metal ring holding the specimen is fixed in vertical direction by a thread bar and nut before the brushing starts.

As a result of this analysis, a completely revised device for the brush test was constructed. An overview of the new brush testing device is depicted in Fig. 4. A standard milling machine was adapted to meet the requirements of the standard. The hand wheel usually used to set the milling head was replaced by a deflection pulley (G) carrying weights (F) that apply the contact pressure from above to the specimen using gravity. The milling head itself was replaced by a clamp for the brush. One main advantage of the system is that the brush can be moved in vertical direction throughout the test to ensure a constant contact pressure. The change in the height of the specimen due to abrasion is now adjusted by the moving brush. The eccentricity of the epicyclical motion of the brush can also be set in a wide range, so that specimens with a diameter of 100 mm and 150 mm can be brushed covering the entire surface. The specimen itself is fixed by clamping jaws (D) with a variable diameter. Thus, the position of the specimen is fixed and always centered below the brush.

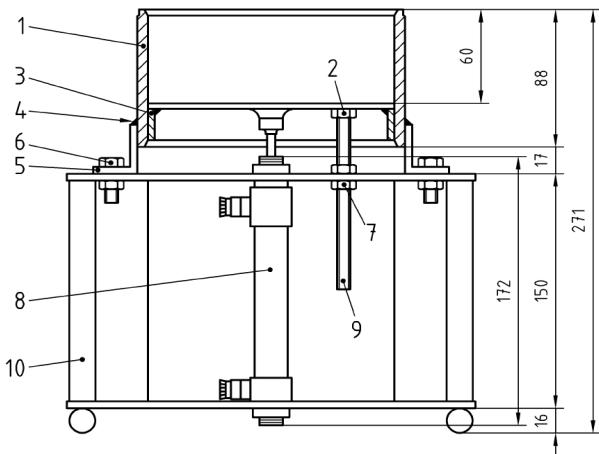


Fig. 3 Example for the frame for brush testing (EN-12697-43) (left); brush test device acc. to EN 12697-43 and detail of the brush test [7] (right).

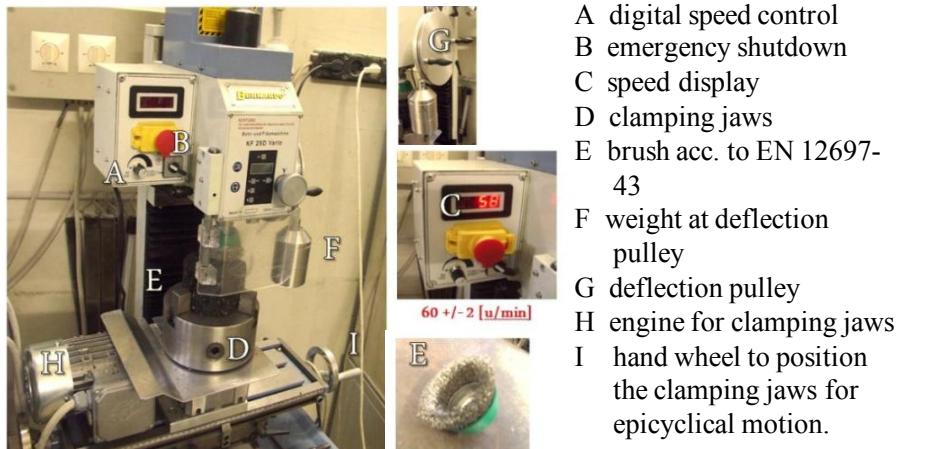


Fig. 4 Improved brush test device from a remodeled milling machine.

As the drawbacks of the device given by the standard are overcome by the test machine presented above, tests to assess the resistance of fuel of HMA could now be carried out producing comparable and repeatable results with an easy-to-handle device that guarantees to meet all requirements given by the EN 12697-43.

5. Further Influences on the Test Results

In the first test program using the new device, the main influences of test conditions set by the standard were isolated. Besides different methods of specimen preparation and cleaning of the specimens after exposure already analyzed above, the influence of the duration of exposure, different contact pressures for the brush test and different fuel types were investigated.

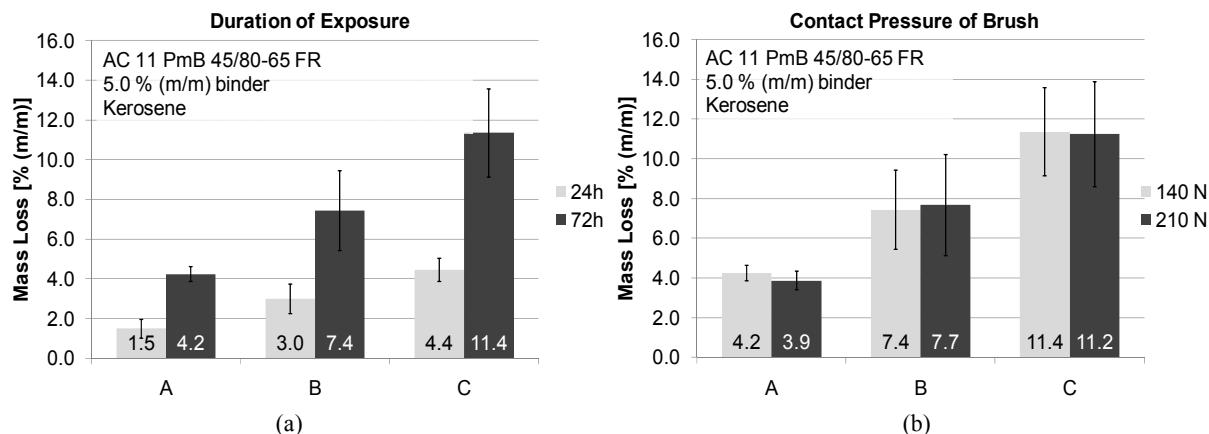


Fig. 5 Impact of (a) duration of exposure; (b) contact pressure of the brush.

- A digital speed control
- B emergency shutdown
- C speed display
- D clamping jaws
- E brush acc. to EN 12697-43
- F weight at deflection pulley
- G deflection pulley
- H engine for clamping jaws
- I hand wheel to position the clamping jaws for epicyclical motion.

5.1 Duration of Exposure

To analyze the influence of the duration of exposure, specimens prepared by roller compaction (according to EN 12697-32) were tested with different immersion times. As an example, Fig. 5a gives the results for an AC 11 PmB 45/80 FR and binder content of 5.0% (m/m). Four specimens were exposed for 24 h, another four for 72 h in jet fuel (kerosene). As the volume of air voids is similar for all specimens (MV : 4.7% (v/v), SD : 0.5% (v/v)), the diagram shows MV and SD for the results of the two conditions.

The duration of exposure has a significant influence on the results. When the duration is increased by the factor of 3 from 24 h to 72 h, the mass loss due to exposure increases by a factor of 2.8 and the mass loss due to abrasion by a factor of 2.5.

5.2 Contact Pressure of Brush

For the same mix as stated in Section 5.1, the contact pressure was varied while brushing. In one case, 140 N were used as required by the standard. In the other case, the weight was increased by 50% to 210 N. Fig. 5b gives information about the results. There is no significantly influence on the mass lost after abrasion (parameter *B*) due to a higher contact pressure. Thus it can be stated that the test seems to be insensitive to moderate changes in the contact pressure between brush and specimen. This might be explainable by the flexibility of the brush hair. A higher weight on the brush leads to greater deformation of the brush hair rather than a stronger abrasive force.

5.3 Fuel Type

Specimens of an AC 11 PmB 45/80-65 mix with 5.3% binder by mass were exposed to two different fuels (benzine and diesel) to find relevant influences of major fuel types. The specimens were exposed to the fuel for 72 h and then brushed acc. to EN 12697-43.

Three diagrams in Fig. 6 show parameters *A*, *B* and *C* vs. volume of air voids of the specimens including a linear regression to show dependencies on the volume of air voids. The upper-left diagram presents the results for mass loss after exposure (parameter *A*). Obviously, benzine shows the most aggressive behavior with more than 40% mass loss for the specimens at a higher volume of air voids. Diesel shows significantly lower aggressiveness. The volume of air voids has a crucial influence on mass loss due to exposure for benzine, less impact for diesel.

Parameter *B*, the mass loss due to abrasion is dependent on the volume of air voids to a much lower extent, but there is still an increasing trend. Exposure to benzine leads to lower resistance of the tested material to abrasive loading.

The combined parameter *C* reflects the situation

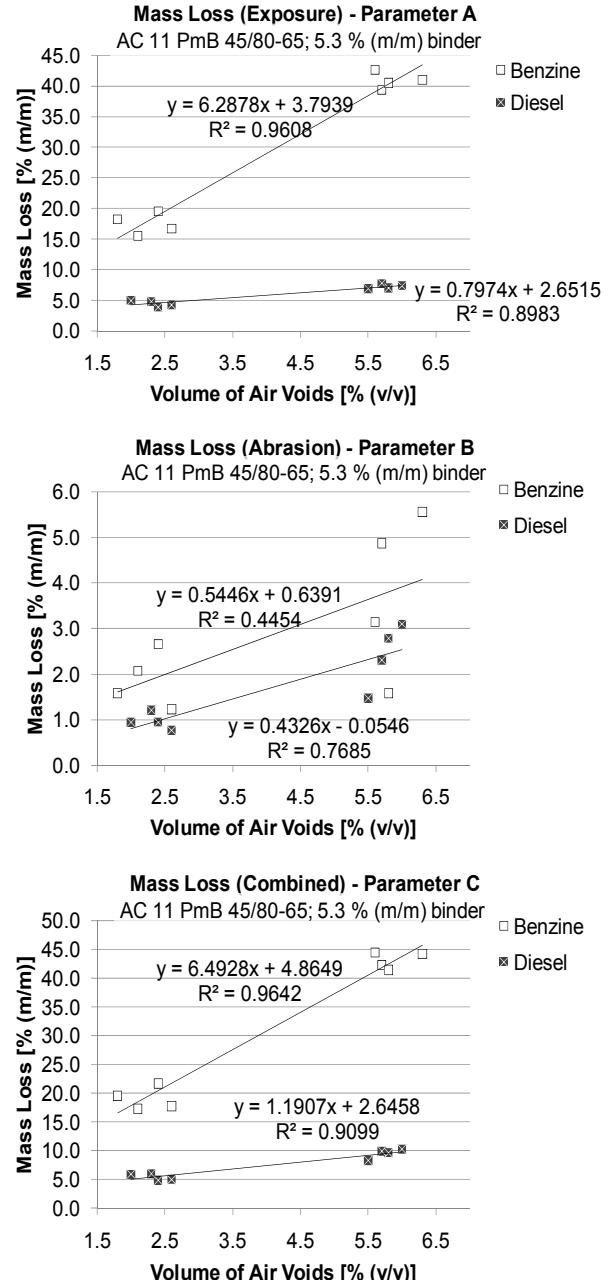


Fig. 6 Influence of fuel type on resistance.

found for parameter *A* and *B*. Benzine is more aggressive showing a strong dependency on the volume of air voids. There is also an increasing trend for diesel but with a much lower slope.

6. Conclusions

From the research and the review of EN 12697-43, it is concluded that the standard is a sound basis for

the assessment of fuel resistance of HMA with potential for improvement.

The suggestion is to implement the roller compactor into the standard EN 12697-33, especially because the roller compactor reproduces the compaction method used in road construction in the most reliable way.

It is recommended to set the height of the specimen produced in the laboratory in the standard more strictly (e.g. 63.5 ± 2 mm) or the immersed part of the specimen relative to its height (e.g. $50\% \pm 1\%$) to make sure that results from specimens with different heights can be compared.

A critical point is the cleaning of the specimen after exposure. The standard is imprecise in this point. As the research revealed, the method of washing and removing of loose particles significantly influences the results. Thus, the method of cleaning must be precisely given by the standard.

A new parameter C was implemented that combines mass loss after exposure and brush testing. This parameter is independent of the method of cleaning. It is recommended to implement C into EN 12697-43 and to obtain the fuel resistance according to parameter C to ensure comparable and repeatable results.

A second example of a brush testing device should be given by the standard. The device constructed in the project is easy-to-handle, ensures that the requirements of the standards are met and produces comparable and repeatable results.

Regarding other influences of test conditions on the results, the duration of exposure has a significant

impact as well as the type of fuel. Also, the volume of air voids has a clear impact on the test results. The weight pressing the brush to the specimen in the brush test was also varied but showed no significant change in the results.

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